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THE LIFE OF THE UNIVERSE

BY

SVANTE ARRHENIUS

VOL. I

HARPER & BROTHERS
LONDON & NEW YORK

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Astron

THE LIFE OF THE UNIVERSE

AS CONCEIVED BY MAN FROM THE EARLIEST AGES TO THE PRESENT TIME

BY

SVANTE ARRHENIUS

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ILLUSTRATED

IN TWO VOLUMES

VOL. I

LONDON AND NEW YORK

HARPER & BROTHERS

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AUTHOR'S PREFACE

MY book, "Worlds in the Making," has been received with such general approval that I do not know how to express my thanks adequately. The work has called forth the most varied questions both from friends and strangers. Many of these questions concern the correctness of the manifold cosmogonic conceptions which were more general in the past than now. These questions, as well as other circumstances, induced me to trace the historical development of cosmogonic ideas from ancient days up to the time of Newton. I have become so profoundly interested in this research that I venture to think the public will be glad to read how the grand speculations of our age have been evolved from the primitive, childlike and incoherent notions of our ancestors in bygone ages. "Nur durch Werden," Haeckel says, "wird das Ge-

wordene erkannt.—A true understanding of phenomena can only be acquired by the study of the history of their evolution."

Haeckel possibly went too far with this statement. The modern chemist need not know all the phantasms of the alchemists. But nobody will question that the study of the views and reasoning of past ages sheds a remarkable light on the views of our own age.

The most interesting feature in such a research is perhaps that it enables us to trace the rudiments of our modern theories from the shadowy notions of antiquity. We watch the fate of theses, observe how they changed with their surroundings, how they competed with other doctrines, how they decayed, to gain strength again and to eclipse their rivals, and how they alone retained sufficient vigour finally. This comparative historical study impresses us also with the soundness and reliability of modern opinions.

We further observe with deep satisfaction how evolution progresses at an unprecedented rate in our days. Human intellect was hibernating for a hundred thousand years, and man did not learn more in any domain than what the lowest races

know at present. During the space of scarcely ten thousand years which we assign to the history of civilisation, much greater progress has no doubt been made than during the whole of the prehistoric ages. There was a sad cultural retrogression during the Middle Ages. Yet we may assert that we have advanced more in the last thousand years than in all the previous ages together. And again, with all admiration for the eminent work which Laplace and Herschel did a hundred years ago, we may assert that the last hundred years have helped us on more than the nine hundred previous years. The application of the mechanical theory of heat to cosmogonic problems alone has done more to elucidate those problems than all the previous investigations, and when we think of the vast fields which spectrum analysis and the study of thermal radiation, of the radiation pressure, and of radioactivity have opened up to us, the balance will decidedly turn in favour of the past century. It is true that we cannot anticipate the judgment which the future may pass on the real achievements of the present age. Yet no scientist will dispute the fact that science has never advanced so rapidly as in our time.

When we ask ourselves, how such extraordinary strides could have been made in natural philosophy, especially in its application to cosmogonic problems, we may reason somewhat as follows: During the dawn of civilisation man lived in small tribes which had grown out of families. The sum-total of the knowledge and experience which the tribe had acquired, independently of other tribes, could not but be limited. The most intelligent man of the tribe, the medicine man, made the best use of his knowledge with the object of ruling the others. Only his trusted confidants were allowed to gain an insight into the science to which he owed his superior position. Successive generations could not add much to that treasure of knowledge. Matters improved when the tribes united to nations. The wise men formed a relatively large caste of priests, who trained in schools those whom they wished to initiate. People had meanwhile learned to put their knowledge and thoughts down in writing. But the written document demanded laborious preparation; the few manuscripts were carefully preserved in the temples. It was not yet deemed wise to impart knowledge to the people; learning

was venerated as something supernatural. Yet great progress was made. The Egyptian priests seem to have been the intellectual leaders; to them the Greek philosophers were indebted for a great deal of their learning. We have all the more admiration for this period of scientific eminence, as a profound reaction soon set in. The manuscripts no longer remained the exclusive property of the priesthood, but became accessible to others, though only to the wealthy. The slaves, who, when Greece and Rome were at their prime, constituted the majority of the people, were not allowed to participate in the spreading of intelligence; the few learned slaves who had to copy manuscripts formed an exception. Manual labour and consequently experimental research were considered unworthy of the free citizen and were left to slaves; that was a baneful prejudice. The philosophical school at Athens, moreover, deprecated the study of nature; philosophers of that school later became eminent leaders in the Christian Church, and the Middle Ages could not shake off their detrimental influence. Decline and stagnation followed. With the discovery of the art of printing and the general intellectual

awakening the contempt of experimental work vanished again. Progress was slow, however, in the struggle against deeply rooted prejudices and for want of co-operation between the different investigators. When these obstacles had been overcome, the number of workers and their means of research multiplied. Hence the grand advance of our time.

We are sometimes told that we live " in the best of worlds." We are not prepared to say whether that be so or not. But we—the scientists in any case—may assert that we live in the best of ages. In the firm hope that the future will be better still, we say with Goethe :

"Es ist ein gross Ergötzen,
Sich in den Geist der Zeiten zu versetzen,
Zu schauen, wie vor uns ein weiser Mann gedacht,
Und wie wir's dann zuletzt so herrlich weit gebracht."

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THE LIFE OF THE UNIVERSE

I

COSMOGONIES OF PRIMITIVE RACES

THE human races on the lowest grade of evolution live merely for the day. The tomorrow and the yesterday have no interest for them, except in so far as their special daily cares are directly touched. Considerations about the Universe and its progressive development do not concern them any more than thoughts about the appearance of the Earth in bygone ages. Tribes of this low state of evolution are found in different parts of the globe at great distances from one another. Thus, Dr. Brinton tells us, it never occurred to the Esquimaux of the North American Arctic seas that the Earth had had a beginning. The Abipones, a once warlike, now peaceful, Indian tribe of Santa Fé, in the Argentine Republic, and the Bushmen of South Africa, do not

appear to have troubled any more about the origin of the world.

Where the struggle of existence is not too hard, however, questions as to the origin of the Earth and of the heavens—or, in other words, of the things outside the Earth—suggested themselves at early stages. Some anthropomorphic conception of the origin of the world is the usual thing. The world must have been created by some personal being. This being had some material at his disposal out of which to shape the world. The notion that the world must have been created out of nothing does not appear to be compatible with primitive conceptions, but to indicate a higher degree of abstraction.*

It seems to have originated with the Indian philosophers, and we meet with it in the legends of Brahma, the spirit, who created, by his thought, the primeval water, as well as in the Persian-Ismaelitic myth of the infinite nameless Being from whom the world emanated in six periods. This belief, that matter can arise from something immaterial by an act of the will, a command, or a thought, we have every reason to characterise as supernatural or unnatural. It contradicts the present standpoint of natural science, according to which the amount of matter is invariable, and

* A very low Australian tribe, the Bu-nu-rong, tell that the God Bun-jel created the world in the shape of an eagle; out of what, is not said.

it was already incompatible with the primitive experiences which the oldest races gathered from their surroundings. Hence we find in most cases the idea of the eternity of matter more deeply rooted apparently, than the view that the personality, the creator, who shaped the world out of matter, must have an unlimited existence. The creator of the Universe is as a rule assumed to have himself originated from primordial matter. We must not look for any higher degree of consistency in these first attempts of speculating upon the origin of the Universe. But we must not overlook either that we meet in the most ancient conceptions rather the germ of the theory of evolution (the theory of the natural development of the Universe under the influence of recognised natural forces which must always have been at work) than any metaphysical theory of creation which, in opposition to the theory of evolution, presupposes the intervention of supernatural forces and cannot therefore be submitted to scientific examination.

The great philosopher Herbert Spencer characterises evolution as a change from the homogeneous to the heterogeneous, from the indefinite to the definite, from the incoherent to the coherent.

This definition—which is not quite correct, especially not as regards the movement of the molecules—corresponds exactly to the first conceptions

of the developments of the Universe, conceptions which prevailed into our age thanks largely to the universal recognition which the theory of Laplace had gained. Water was generally accepted as the primordial element, perfectly homogeneous, without shape, without order. That the fertilising mud was deposited by floods, could not fail to attract the attention of ancient races. They naturally came to the assumption that all the earth had slowly and gradually been deposited from the water. Thales says (about 550 years before the beginning of our era) that all things arise from the water. The observation that water leaves, in the vessel in which it is being boiled, an earthy crust consisting of salts dissolved in the water and of suspended matter, was probably made in the early ages.

One of the Hindu myths concerning the origin of the world may be quoted as exemplifying these beliefs. Egyptian, Chaldæan, Finnish creation lores will be mentioned lower down. The grand 129th Hymn of the 10th book of the Rig-Veda reads, in J. Muir's translation :

> There then was neither Naught nor Aught,
> no air, no sky beyond.
> What covered all ? Where rested all ?
> In Watery Gulf profound ?
>
> Nor death was then, nor deathlessness,
> nor change of night and day.
> That One breathed calmly, self-sustained,
> Naught else beyond It lay.

Gloom, bid in gloom, existed first,
One Sea eluding view.
That One, a void in chaos wrapt,
By inward fervour grew.

Within It first arose desire,
the primal germ of mind
Which nothing but existence links,
as sages searching find.

The kindling ray that shot across
the dark and drear abyss—
Was it beneath? or high aloft?
What bard can answer this?

There fecundating powers were found,
and mighty forces strove—
A self-supporting mass beneath,
and energy above.

Who knows, who ever told, from whence
this great creation rose?
No gods had then been born,—then who
can e'er the truth disclose?

Whence sprang this world, and whether framed
by hand divine or no—
Its Lord in heaven alone can tell—
If even He can show.

This profound, beautiful hymn cannot be classed with the lore of primitive races; it indicates a very high stage of evolution. But the belief in the primordial water as origin of all things was no doubt deeply rooted in the most ancient notions of the East-Indian races.

The idea which reoccurs in a great many crea-

tion myths (among others in the Chaldæan and in the Hebrew which is related to it, as well as in the Greek), that the darkness or the night, which is nothing but absence of light, should be something real, is very characteristic. The Naught is made cognate with the Aught, although they are in direct contradiction. The fundamental idea was, no doubt, that in a perfectly uniform Chaos no object could be distinguished from its surroundings, and that there was no separate existence therefore.

The orderless stage and condition is as a rule designated by the Greek word Chaos, which signifies everywhere uniformly distributed, shapeless matter. Kant in his cosmogony also starts from the idea that the world in the beginning was a perfectly uniform chaos of material particles. The original state is sometimes characterised by the term primordial æther, as in the Japanese creative lore: "In the early ages," we read, "when Heaven and Earth were not separated from one another, there was only the primordial æther, a mixture which resembled an egg. The clear floated upward, as it was lighter, and became the Heavens; the heavier turbidity sank into the water and became the Earth." According to another Japanese legend, which Tylor has related, "the Earth was still soft like mud or like oil floating on the surface of the water, when there arose out of the mass a flag or rush, called

'Asi,' from which there springs the land-forming God."

The simile of living nature, in which the organism springs from an apparently lifeless seed or an egg, has made the egg a common element in creation myths. We find it, as just mentioned, in the Japanese legends, as well as in narratives which come from India, China, Polynesia, Finland, Egypt, and Phœnicia. Among the creation myths according to which one or several eggs played an important part in the origin of the world, the Finnish legend is the best known and the best worked out. It has been written down from the tradition of the relatively uncivilised tribes which inhabit the Russian government of Archangelsk. According to this tradition, "one of the chaste maids of Nature, Ilmatar," floated in the blue space and descended upon the billows of the sea. We have therefore from the beginning the sea, above it the wide space, and Ilmatar, who came from Nature. This is in agreement with the common conception of primitive races.

For seven centuries now Ilmatar, rocked by the tempest, floats on the waves. A teal comes flying across the water, looking for a place where to build its nest. Ilmatar raises her knee from the water, and the teal lays on it six golden eggs and a seventh egg of iron. After the teal has been brooding for two days, Ilmatar stirs, and the eggs fall down into the depth.

In the ooze they were not wasted
nor the fragments in the water ;
But a wondrous change came o'er them,
and the fragments all grew lovely.
From the cracked egg's lower fragment
now the solid Earth was fashioned.
From the cracked egg's upper fragment
rose the lofty arch of Heaven.
From the yolk the upper portion
now became the Sun's bright lustre ;
From the white the upper portion,
rose the Moon that shines so brightly.
What so in the egg was mottled,
now became the stars in heaven.
What so in the egg was blackish,
in the air as cloudlets floated.

(From W. E. Kirby's English version of the Kalevala).

Then Ilmatar rises from the sea and creates the jutting headlands, the islands, mountains and hills, and brings forth Väinämöinen, the immortal bard, the son of the Wind. Väinämöinen rejoices over the splendour of the Moon and of the Sun, but he complains that the Earth does not bear any plants. He calls upon the god of agriculture, Pellervoinen, who strews seeds over the fields. The fields become covered with lively green, and trees begin to grow. The oak finally grows so powerfully that it obscures the light of the Sun and the Moon from man, so that it must be felled.—We see that in the course of the narrative there enter gods, men, animals, and plants without any further indication of the whence they came. This feature is typical in creation myths,

but it is rarely so pronounced as in the Finnish legend. Different portions of this Kalevala saga were probably related by different people; there is no revision of the whole of the saga concerning the creation of the world. The myth is, in other words, a poem of the child of Nature, and not the world-embracing thought of the brooding philosopher.

"The original cosmogonies," E. G. Hirsch writes, "are the spontaneous production of folk-fancy and are therefore unsystematic, forming as a rule only chapters of the theogonies or genealogies of gods."

The deluges, to which scientists have devoted much attention, are prominent features of the creation myths of different races. The biblical deluge is best known: the Earth was altogether flooded; even the highest mountains were fifteen cubits under the surface of the waters. In the 'seventies, a cuneiform inscription of similar character was found in which the hero Sit-napistim (the Xisusthros of the Babylonians) is mentioned; since then it has been assumed that the Hebrew legend was taken from an Assyrian source. The Hebrew text says: "I will make a flood come from the water," and the celebrated geologist Suess (1883) suggested, therefore, that the deluge had been caused by a flood accompanying some volcanic eruption, and had spread from the Persian Gulf over the valley of Mesopotamia.

I. Riem has collected no fewer than sixty-eight deluge myths of different races, which all appear to be independent of one another. Of these only four concern European nations, viz.: the Greek myth of Deukalion and Pyrrha, the narrative of the Edda, and the sagas of the Lithuanians and of the Wogules of North-east Russia. From Africa hail five, from Asia thirteen, from Australia and Polynesia nine, from North and South America thirty-seven of these narratives. The Negroes, Kafirs, and Arabs do not know similar legends. The cause of the great flood is very different with the different nations. It is stated to have been the melting of the snow and ice in Scandinavia, rain in Assyria, the fall of snow (Montagnais-Indians), the collapse of the heavens by fracture of their pillars (China), the revenge of the water-god (natives of the Society Islands), etc. In some cases we are told that the deluges were repeated several times. Thus Plato says in Timæos that an Egyptian priest had informed him, that the deluges of the heavens would reoccur in definite periods.

The common idea is, that the act of the creation merely consisted in arranging the orderless matter, in most cases by the separation of the earth from the primeval water or ocean. Some primitive tribes of the islands of the Pacific imagine the earth to have been fished up from the ocean. It was to be expected that the previous orderless

state would itself be ascribed to a flood or a deluge which was afterwards repeated. The Santales, who are not Aryans, are credited with such ideas, for instance.

This agrees with the views held by some modern scientists that the actually inhabited part of the world will some day be devastated, once more to bear new life later on. With the primitive races it is water or fire or wind, sometimes also the wrath of the gods which causes the devastation, after which the Earth will re-develop again to become the abode of living beings. The change is supposed to have taken place several times. This widely spread view has found its most complete expression in the Indian myth (in the books of Purana) and in the Buddhistic philosophy, to which we shall return.

The doctrine of a palingenesia or regeneration of the world is commonly associated with the very general belief in metempsychosis (transmigration of the soul), which problem we need not discuss in this connection.

The ancient American myths of the Red Indians have a certain interest. Although presumably produced without any intervention from the Old World, they show a striking similarity to the legends of the latter ; but the animals play a far more important part with the Indians. Like most people devoted to the chase, the American Indians regard the animals as of their own kind. The

shaper of the world generally appears to have had some earth or loam at hand. As a rule the earth was precipitated from the water. The most simple notion is that a small island in the ocean gradually grew to the size of the world. Characteristic is the idea of the Takulians of British Columbia, that there was nothing but water and the musk rat in the beginning. The musk rat was looking for food on the bottom of the sea. From the mud which collected in its mouth and which it spit out an island formed which grew to the continent. A still more peculiar myth we find with the Iroquois, who relate that a goddess was hurled from the heavens and fell upon a tortoise swimming in the water, which enlarged into the continent. The tortoise evidently corresponds to the small island of the sea of the first-mentioned myth, and the fall of the goddess from the heavens only gave the impulse to the development. The Tinneh Indians believe that the body of a dog, who could also assume the shape of a beautiful youth, was torn by giants and transformed into the objects which are now found in the world. This myth, that the world had been created out of the members of a human or animal body, is met with in the sagas of many primitive races. Sometimes, as with the Winnebago Indians, the creator Kitchi Manitu (the Great Spirit) takes some limb of his own body and a lump of earth to shape from them the first man. That legend, which so

strikingly resembles the Hebrew story of the creation of Eve, distinctly implies that the Earth had been in existence from the beginning. The same applies to the traditions of the Navajo Indians, the Digger Indians, and the original inhabitants of Guatemala.

The natives of Australia are a race of the lowest type. They do not, on the whole, appear to have meditated on the beginning of the world. For them, as for most uncivilised peoples, the heavens are a firm dome over the flat disc of the Earth. The Wotjobaluk tribe believes, that the heavens had first been pressed down firmly upon the Earth; the Sun could not move between them, until a magpie lifted the Sun up to the heavens by means of a long stick. This extremely naive story recalls a similar myth of the old Egyptians to which we shall refer later on.

All these examples illustrate, how strongly the primitive conceptions of the construction of the Universe are interwoven and interconnected with religious beliefs. The savage considers everything that moves, everything that exercises some effect, as endowed with a spirit controlled by will. This conception is termed animism. "If a stream is gifted with life like a human being, then it may, according to its own will, bring blessing by irrigation or injury by violent floods. Then it will be necessary to pacify the stream that it may fertilise, or to induce it to refrain from devastating floods."

Primitive man endeavours to propitiate the powerful spirit by sorcery, knowledge of which is only given to the medicine man or to the priest and is not granted to the other mortals. The means of utilising the forces of nature, which we hope to acquire by studying nature and natural phenomena, primitive man endeavours to gain by magic. In a certain sense magic is therefore the precursor of natural science, and the myths and lore, upon which the practice of magic is based, correspond to a certain extent to our scientific theories. Myths are, according to Andrew Lang, just as much based upon primitive science, resting on supposition, as upon primitive religious conceptions. We easily comprehend that these suppositions started from observations of everyday life, and it is not difficult to divine which observations were particularly concerned. Chance may have been at work sometimes.

Tradition handed these myths down from barbaric ages to periods of higher civilisation. Reverence for the convictions inherited from the ancestors prevented the superior understanding of later ages from revising the ancient myths and from eliminating the elements which seemed to be incompatible with the advanced knowledge. This fact stands out distinctly in the cosmogonies of Hesiod and of Ovid to which we shall return in the next chapter.

Frequently we further notice another influence.

MYTHS OF PRIMITIVE RACES

The myths of primitive races were in most cases written down by persons of high intelligence. Unconsciously the simple narrative of the child became tinged with the narrator's own conception. This is all the more so, because the myths lacked a consistent sequence, which the compiler naturally felt tempted to introduce. That would happen particularly when tribal relationship and other reasons favourably predisposed the compiler towards the people. In such cases the myth becomes transformed into a beautiful epic, based upon motives adapted from the primitive race.

Matters will be different when written documents have been preserved. To produce such requires a higher state of culture, and we cannot well assert that the documents originated with the primitive races. The cosmogonies which written tradition has handed down to us shall therefore be dealt with in a special chapter. Among these two groups deserve particular attention. Firstly the group of nations from whom we have inherited important elements of civilisation; secondly the group of nations which were endowed with a high degree of intelligence and philosophical depth.

The first group is directly connected with the views which the philosophers of ancient times and the thinkers of more modern ages have modified and developed. Remnants of cosmogonical traditions of the ancient civilised peoples

constitute an essential portion of the conceptions of the Universe held by the civilised peoples of our own age.

The second group interests us particularly because the wonderful achievements of modern science bring back to us many an ancient idea concerning the other worlds.

II

CREATION MYTHS OF ANCIENT CIVILISED RACES

MODERN civilisation has its root in ancient Chaldæa and Egypt. We find in these countries art monuments which have been preserved for 7000 years. Traces of a still more ancient civilisation, which may go back some 50,000 years, have indeed been discovered in the limestone grottos of Southern France and Northern Spain. The walls of these grottos are covered with coloured sketches, chiefly of animals like the mammoth, the reindeer, and horse. But the fantasy of the artist of those primeval days was only interested in the spoil of the chase and a little in the woman with whom he was going to divide his spoil, when there was plenty of it. That remote period has not exercised any influence upon the civilisation of our age. All the greater has been the influence of the other periods which point back to the classical soils of Chaldæa and of Egypt.

In the time when there was nothing up above what we call heaven, and nothing below that had

the name of earth, that is to say, when neither earth nor heaven existed, says the Chaldæan myth, there was only Apsu (the Ocean), the father, and Tiamat (Chaos), the All-mother. The water of the ocean and chaos intermixed. From the union, which contained the primordial elements of our Universe, life germinated. Gods also arose, "who had not been created before," and they brought forth a numerous progeny. When Tiamat saw that the hosts of gods took more and more possession of her territory, she created an army of monsters, bulls with men's heads and dogs with fish-tails and others, to defend her own dominion. Then the gods took counsel and resolved to destroy the monsters; but no one dared except Marduk, the son of the god of wisdom Ea. He, however, wrung from his fellow deities the promise of supremacy, as prize for his victory. When the prize had been conceded, under the stress of circumstances, Marduk, armed with bow, spear, and thunderbolt, pursued Tiamat, and threw a net over her (Fig. 1). When Tiamat opened her wide mouth in order to devour Marduk, he threw the hurricane into her throat and her entrails, and Tiamat burst. Her adherents attempted to flee horror-struck; but they were fettered and brought before Ea's throne. Marduk then reshaped Tiamat's body, the orderless Chaos. He divided it into two halves, "as one does with fishes which are to be dried." "Then he suspended the one half up

FIG. 1. Marduk armed with lightning kills Tiamat. Drawn by Faucher-Gudin after a bas-relief from Nimrud, in the British Museum.

This and the following three illustrations from Maspero, "Histoire Ancienne des Peuples de l'Orient Classique."

high, and that became the Heavens, and the other half he spread underneath his feet, and that became the Earth ; and thus he made the world as man has known it since."

In Maspero's "Histoire Ancienne des Peuples de l'Orient Classique" we find a picture (see Fig. 2, p. 21) of how the Chaldæans imagined the Universe. Surrounded on all sides by the ocean, the Earth rises in the middle like a high mountain, whose summit is covered with snow from which the Euphrates springs. The Earth is all round encircled by a high wall, and in the depth between the Earth and the wall lies the ocean which no mortal can traverse. Beyond it is the abode of the Immortals. Over the wall rests a vault, the firmament, which Marduk shaped out of hard metal, that shines in the daytime in the splendour of the Sun, but which resembles at night a dark blue bell set with stars. In the northern part of the vault is a semicircular gallery provided with two entrances, one in the east, the other in the west. In the morning the Sun emerged from the eastern opening, slowly to rise higher and higher over the southern sky and then to sink down to the western opening, into which it entered at night. During the night the Sun was gliding through the gallery, to start on its journey again the following morning. Marduk arranged the year according to the course of the Sun and divided it into twelve months, each of which

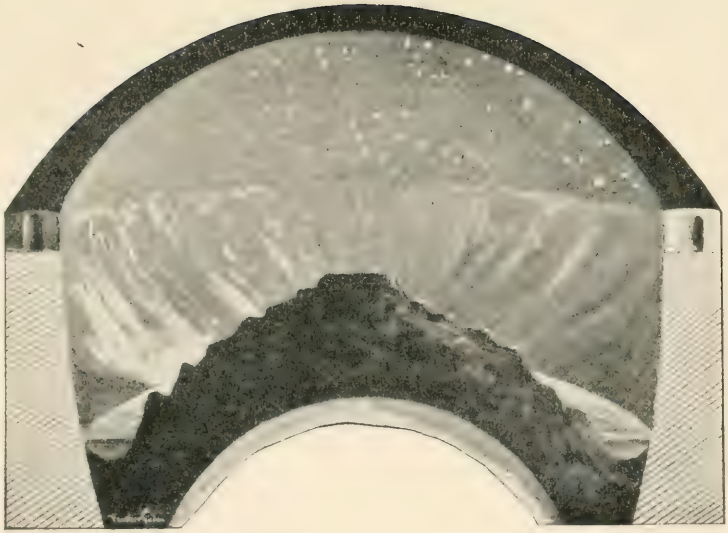


FIG. 2. Chaldæan picture of the World. Drawn by Faucher-Gudin. In the centre is the continent, which rises from all sides to the mountain of the world, the Ararat. The land is all surrounded by the ocean, beyond which lies the abode of the gods. Above the mountain of the Universe the heaven is vaulted like a bell (created by the god Marduk) which was shining in the splendour of the Sun in the daytime, and appeared dark blue and strewn with stars during the night. The northern portion was provided with a gallery, whose openings can be seen in the picture. The Sun issued from the eastern opening in the morning and rose on the firmament to sink down in the afternoon, finally to re-enter the western opening of the gallery. During the night the Sun was gliding through the conduit to reissue from it on the following morning.

counted three periods (decades) of ten days ; the year therefore numbered 360 days. Every sixth year a special month was intercalated, so that the year had on average 365 days.

As the life of the Chaldæans was to a high degree influenced by the changes in the seasons, the Chaldæans laid great stress upon the time division. In the beginning they probably had based their chronology upon the movements of the Moon, like most other races. They soon recognised, however, that the Sun exercised a stronger influence, and they introduced a solar year, whose division is ascribed to Marduk. The stars were observed because their positions determine the seasons. And since the seasons rule organic life, upon which mankind is altogether dependent, that pernicious exaggerated belief in the power of the stars took root which prevailed for twenty centuries and which crippled the advance of science up to the beginning of the modern era. Diodorus Siculus, a contemporary of Julius Cæsar, expressed this belief in the following words :

" The Chaldæans having for long ages watched the stars and observed their motions and laws more carefully than other nations were empowered to predict much of what was going to happen to man. The greatest influence upon the future and the highest prophetical importance they attached to the five stars which we call Planets, Mercury, Venus, Mars, Jupiter and Saturn, but which they

comprised under the name of 'interpreters.' . . . But in the paths of these stars there are, they say, thirty others which they designate 'advisory deities.' Their supreme deities are twelve, and to each of these they assign one month and one of the twelve constellations in the Zodiac. Through these constellations, they maintain, Sun, Moon and the Planets take their orbits."

The Chaldæan priesthood had elaborated a perfect astrology. They carefully mapped out the positions of the stars for every day, and they could calculate the future positions of the stars for some time in advance. The different stars either represented deities or were directly identified with them. If, therefore, somebody wished to know, which gods ruled over his own destiny, he consulted the star-wise priests as to the positions of the stars on his birthday, and on payment of an ample fee he was informed of the chief events of his fate. When a great undertaking was projected for a certain day, the chances of its happy issue could be ascertained in advance. Benevolently to judge we may perhaps say, that the basis of the teachings of these priests was the conviction, which is universal at the present time, that every event is a necessary consequence of external conditions.

But this view is intimately connected with another which is entirely erroneous and which will not bear any close examination, viz. that the

positions of the Moon and of the Planets can exercise a noteworthy influence upon Nature and upon man. The belief that the celestial bodies were gods, transformed astronomy into a part of theogony, i.e. of religion. Religious cult was the exclusive domain of the ruling priest caste. To utter doubts of the preconceived tenets of this caste was to expose oneself to merciless persecution by the powers who had common interests with the priests. This terrible oriental trait passed to a certain extent over to the nations of classical antiquity and to a high degree to the semi-barbarians of the Middle Ages.

The Chaldæan conception of the shaping of the Universe is further of great importance for us, because it was, although modified, taken up by the Jews and with them by the Christians. How modern research supposes this creation myth to have spread is well set forth in the book, " Babel und Bibel," to which we should like to direct attention. Chaos was for the Jews the primeval; the earth was without form and void, and darkness was upon the face of the depths (upon the primordial waters). The Babylonian priest Berosos states that everything was darkness and water in the beginning. The Hebrew narrative regards the depth, Tehom, as a personality, and Tehom corresponds etymologically to Tiamat. From the existent matter Elohim created (or rather carved) the Heavens and the Earth.

FIG. 3. The god Shû, separating Nûit (the Heavens) and Sibû (the Earth). Drawn by Faucher-Gudin after a painting on one of the mummy sarcophagi in the Turin Museum.

Elohim divided the waters. The waters above were enclosed in the Heavens, the Earth, flat or hemispherical, was placed in the lower waters on which it was floating. Above the waters was the immovable firmament to which the stars were fixed. But it was by no means a long way up to the firmament of Heavens; the birds could rise up to it, and fly along it. Enoch describes, how several stars were consumed by the fire of Gehenna because they did not begin to shine when Elohim had ordered it. The stars are hence wicked angels, gods who had been deposed by the supreme God.

The chief difference between the Chaldæan and the Hebrew myth lies in the fact that the latter is monotheistic, the former polytheistic, though with a tendency towards monotheism, inasmuch as the sun-god Marduk, who ruled all things, is also the ruler of the gods.

We find in the Jewish cosmogony also a trace of the Phœnician myth of the world-egg in the expression "the spirit of Elohim brooded [as a rule translated: floated or hovered] over the waters." Allusions to the combat between Marduk and Tiamat are also to be found in the legends of the victory of Jahve over the sea-monster Leviathan or Rahab. The Hebrew, and therefore also the Christian representation of the origin of the world cannot be said to be distinguished by any great originality.

Slightly more recent than the first Chaldæan

FIG. 4. The sun-god rising during the creation from a blossoming lotus-flower. Drawn by Faucher-Gudin. On his head the god wears the sun-disk covered by the sacred Uræus snake. The lotus-flower as well as the two buds rise from a zocle, the usual symbol for water basin, here representing the primeval water Nu.

accounts of the beginning of the world, but yet of a very high age, are the corresponding Egyptian narratives. We reproduce the most important myths of this description according to Maspero. The conception of "Nothing" had not yet been abstracted. Matter was, though without form, "in the dark waters," and the respective deity—always a different person in different parts of the land—shaped the objects, both lifeless and alive, now occurring on the earth, by different methods according to his own wont, for example, by weaving or by modelling on a potter's wheel. The most highly developed type of the creative myth is reported from the eastern delta of the Nile. In the beginning Heaven (Nûit) and Earth (Sibû) rested in close embrace in the primordial water (Nu). On the day of the creation a new god Shû arose from the water, seized with both hands the goddess Nûit and lifted her up; she now formed the star-strewn firmament supporting herself on her hands and feet, the four pillars of the firmament (Fig. 3, p. 25).

Sibû then covered herself with green, and animals and men began to people the world. The sun-god Ra had been lying hidden in the bud of a lotus-flower in the primordial water. On the day of the creation the petals of the lotus opened, and Ra stepped forth, to take his place in the heavens (Fig. 4, p. 27). Ra was often identified with Shû. When the Sun was shining upon Nûit and

Sibû, a number of gods were born, among them the Nile-god Osiris. Under the warm rays of the Sun all things alive, plants, animals, and men, began to develop. According to some legends this was due to a kind of fermentation in the mud of the Nile, a process of spontaneous generation, in which historical time retains a certain belief. Some said that the first men, the children of the Sun, were perfectly happy, and that the later race had degenerated and fallen from the original beatitude. Others believed, the oldest human beings had been of animal nature, capable only of inarticulate sounds, until the god Thot had taught them both language and writing. Darwinism, we see, had its precursor in the very child age of civilisation.

The classical age had very undeveloped opinions regarding the origin of the world. Hesiod, about 700 B.C., gives in his theogony and in his " Works and Days " the Greek creation myth.

Everything began with the chaos. Then came the earth goddess, Gäa, the mother of all things ; her own son Uranos, the god of heavens, is generally represented as their father.—Heaven and Earth were often regarded as ancestors of the gods by primitive races.—A critical analysis of the naive, child-like, and in some parts barbaric epic would have little value. We therefore reproduce part of the theogony in poetical versions, after C. A. Elton and J. H. Voss. Elton's translation begins with verse 143 :

Children of Jove, all hail ! but deign to give
th' enchanting song ! record the sacred race
of ever-living gods ; who sprang from earth,
from the starr'd heaven, and from the murky night,
and whom the salt deep nourish'd into life.
Declare how first the gods and earth became,
the rivers and th' immeasurable sea
raging in foamy swell ; the glittering stars,
and the wide heaven above ; and who from these
of deities arose, dispensing good ;
say how their treasures, how their honours each
allotted shared ; how first they fix'd abode
amidst Olympus' many-winding vales.
Tell, O ye muses ! ye who also dwell
in mansions of Olympus, tell me all
from the beginning ; say who first arose.
First Chaos was ; next ample-bosom'd Earth,
the seat immovable for evermore
of those immortals, who the snow-topt heights
inhabit of Olympus, or the glooms
Tatarean in the broad-track'd ground's abyss.
Love, then, arose most beautiful amongst
the deathless deities ; resistless he
of every god and every mortal man
unnerves the limbs ; dissolves the wiser breast
by reason steel'd, and quells the very soul.
From Chaos Erebos and ebon Night :
From Night the Day sprang forth and shining air,
whom to the love of Erebos she gave.
Earth first produced the Heaven ; whose starry cope,
like to herself immense, might compass her
on every side, and be to blessed gods
a mansion unremoved for aye.

Gäa then brought forth the swollen, chafing Sea Pontos. With Uranos she engendered six male and six female children, the Titans ; the deep-eddying Okeanos ; Koios (probably a god of

light, only mentioned by Hesiod); Kreios (a semi-god; his spouse was Eurybia, a daughter of Pontos); Japetus (father of Prometheus, who stole the fire from the gods to give it to man); Hyperion (the name signifies "the high wandering"); Theia (the Magnificent); Rheia (God's-mother, as mother of Zeus); Mnemosyne (goddess of Memory, mother of the goddesses of Song); Themis (goddess of Law and Order); Thetis, Phœbe, and Chronos (Supreme Deity, deposed by his son Zeus), as well as the Cyclops (one-eyed giants whom Apollo slays), and others. It would be of little interest if we were to reproduce the whole versified catalogue, the names of which seem partly to have been invented by Hesiod. This simple kind of poetry, name-invention, was in great favour also with the bards of the Norsemen. The following lines concerning the origin of the stars and of the winds may be quoted in the metrical translation of Johann Heinrich Voss (1751–1826):

Theia gebar voll Glanzes den Helios, und die Selene,
Eos auch, die allen den Erdbewohnern leuchtet,
Und den Unsterblichen rings im weitumwölbenden Himmel:
Diese gebar einst Theia der liebenden Macht Hyperions.
Aber dem Krios gebar Eurybia mächtige Söhne,
Pallas samt Astræos,* die hoch vorragende Göttin,
Perses auch, der vor allem an kundigem Geiste sich ausnahm.
Eos gebar dem Astræos die Wind' unbändigen Mutes,

* Father of the Winds.

Zephyros *, blassumschauert, und Boreas †, stürmisch im
Anlauf.
Notos,‡ da in Liebe zum Gott sich die Göttin gelagert.
Auch den Phosphoros § jetzo gebar die heilige Frühe,
Samt den leuchtenden Sternen, womit sich kränzet der
Himmel.

In " Works and Days " Hesiod depicts how the gods created human beings. They were good at

FIG. 5. The River Okeanos according to Greek myth.

* West. † North.

‡ South. § Morning star, planet Venus.

first, perfect and happy, and lived without toil on the abundance of what the Earth yielded to them. But degeneration befell them.

The Greek cosmogony was adopted by the Romans without undergoing noteworthy development. In the beginning, Ovid says in his "Metamorphoses," it was orderless, shapeless Chaos, "rudis indigestaque moles," a mixture of earth, water, and air. Nature separated the elements, the earth from the heavens (the air) and from the water, and the fine air (the æther) from the coarser (ordinary) air. The fire which "has no weight" rose up to the highest zones of the heavens. The heavy earth soon settled and became all surrounded by water. Nature then formed the bottom of the sea and the beds of rivers, mountains, plains, and valleys. The stars which Chaos had obscured began to shine and became the abode of the gods. Plants, animals, and lastly human beings were created. Man lived in the ideal state of the golden age. Eternal spring was reigning, and the untilled earth bore abundant crops ("fruges tellus inarata ferebat"). The rivers flowed with nectar and milk, and honey dripped from the oaks. When Jupiter (Zeus) had deposed Saturn (Chronos) and imprisoned him in Tartarus, a less blissful age, the silver age, set in. Winter, spring, summer, and autumn succeeded one another; people were obliged to seek shelter from the raw weather.

Matters deteriorated still more in the bronze age; and finally came the terrible iron age, in which modesty, faith, and truth fled from the earth, giving place to fraud, violence, treason, the insatiable thirst of gold, and horrible crimes.

Ovid's cosmogony differs little from that of Hesiod. Much of the original unaffected simplicity has been lost; the sober systematics reflect the practical frame of the Roman mind.

The following verses from the brilliant opening of Ovid's "Metamorphoses" are quoted after John Dryden's translation (published 1717):

Before the Seas, and this terrestrial ball
and Heaven's high canopy that covers all,
One was the Face of Nature; if a Face,
rather a rude and indigested mass:
A lifeless lump, unfashioned and unframed
of jarring seeds, and justly Chaos named.
No Sun was lighted up, the World to view;
No Moon did yet her blunted horns renew;
Nor yet was Earth suspended in the Sky;
Nor pois'd did on her own foundations lie.
Nor Seas about the Shores their Arms had thrown.*
But Earth and Air and Water were in one.
Thus Air was void of Light and Earth unstable
and Water's dark Abyss unnavigable.
No certain form on any was imprest,
all were confused, and each disturbed the rest.

* This verse, according to which Amphitrite, the spouse of the god of the Sea Posidon, embraces the edge of the Earth, shows that Ovid considered the Earth to be a disc, not a sphere. The learned men of Ovid's time, however, all believed in a spherical Earth.

For hot and cold were in one Body fixt
and soft with hard, and light with heavy mixt.
But God or Nature, while they thus contend
to these intestine discords put an end.*
Then Earth from Air, and Seas from Earth were driv'n,
And grosser Air sank from Ætherial Heav'n.
Thus disembroil'd they took their proper place ;
the next of kin, contiguously embrace,
and Foes are sundered by a larger Space.
The force of Fire ascended first on high
and took its dwelling in the vaulted sky ;
Then Air succeeds, in Lightness next to Fire,
Whose atoms from unactive Earth retire.
Earth sinks beneath, and draws a numerous throng
of pondrous, thick unwieldy seeds along.
About her coasts sinuously Waters roar
and, rising on a ridge, insult the Shore.
Thus when the God, whatever God was he,
had formed the whole and made the parts agree,
that no unequal portion might be found,
He moulded Earth into a spacious Round.†
Then with a breath he gave the winds to blow ;
and bade the congregated Waters flow.
He adds the running Springs, and standing Lakes,
and boundary Banks for winding Rivers makes.
Some parts in Earth are swallowed up, the most
in Ample Ocean, disembogu'd are lost.
He shades the Woods, the Valleys he restrains,
With rocky Mountains and extends the Plains.
And as Five Zones th' Ætherial regions bind,
Five correspondent are to Earth assigned ;
The Sun with rays, directly darting down,
Fires all beneath and fries the middle Zone.
The two beneath the distant Poles complain
of endless Winter and perpetual Rain.

* "Hanc deus et melior litem natura diremit."

† "Orbis" originally signified a circular disc, later also a sphere.

Betwixt th' Extremes two happier Climates hold
the Temper that partakes of Hot and Cold.
The Fields of Liquid Air, inclosing all,
surround the compass of this Earthy Ball:
the lighter parts lie next the Fires above,
the grosser near the watry surface move:
Thick clouds are Spread and storms engender there
and Thunder's Voice which Wretched Mortals fear,
and Winds that on their Wings cold Winter bear.

Here follows a description of the winds. The poet proceeds:

High o'er the Clouds and Empty Realms of Wind,
The God a clearer space for Heav'n design'd;
Where Fields of Light and liquid Æther flow;
Purg'd from the pondrous Drags of Earth below.
Scarce had the Pow'r distinguish'd these when straight
The Stars, no longer overlaid with weight,
Exert their Heads, from underneath the Mass,
and upward shoot and kindle as they pass,
and with diffusive Light adorn their heav'nly place.
Then every void of Nature to supply,
with Forms of God he fills the vacant sky:
New herds of beasts he sends the Plains to share,
New Colonies of Birds, to people Air:
and to their Oozy Beds the Fish retire.

A creature of a more exalted kind
was wanting yet, and then was Man design'd.*
Conscious of Thought, of more Capacious Breast,
for Empire form'd, and fit to rule the rest.
Whether with particles of heavenly Fire,
the God of Nature did his soul inspire,
or Earth, but new divided from the Sky,
and pliant still retain'd th' Æthereal Energy:

* Sanctius his animal mentisque capacius altæ—deerat adhuc et quod dominari in cetera posset—natus homo est.

Which wise Prometheus temper'd into paste,
and mixt with living streams, the Godlike Image cast.
Thus while the mute Creation downward bend
their Sight, and to their Earthy Mother tend,
Man looks aloft; and with erected Eyes
Beholds his own hereditary Skies.
From such rude Principles our Form began;
and Earth was metamorphos'd into Man.

The Golden Age was first; when Man yet New
No Rule but uncorrupted Reason knew:
and with a Native bent, did God pursue.
Unforc'd by Punishment, unaw'd by Fear
His Words were simple, and his Soul sincere:
Needless was written Law, where none oppress:
The Law of Man was written in his Breast:
No suppliant Crowds before the Judge appeared,
no Court erected yet, nor Cause was heard:
But all was safe, for Conscience was their guard.
The Mountain-Trees in distant prospect please,
E'er yet the Pine descended to the Seas:
E'er Sails were spread, new Oceans to explore:
and happy Mortals, unconcerned for more,
Confin'd their Wishes to the Native Shore.
No Walls were yet; nor Fence, nor Mote, nor Mound,
Nor Drum was heard, nor Trumpets' angry sound
Nor Swords were forg'd; but void of Care and Crime,
the soft Creation slept away their time.
The teeming Earth, yet guiltless of the Plough,
and unprovok'd did fruitful Stores allow.

Then follows the silver age. The eternal spring of the golden age comes to an end; Jupiter establishes the four seasons. Man had to seek shelter to avoid the burning heat of the summer and the icy cold of the winter. Not satisfied with

what the earth yields voluntarily, man learns to till the ground.

To this came next in course, the Brazen Age :
A Warlike Offspring, prompt to Bloody Rage,
Not Impious yet. Hard Steel succeeded then :
and stubborn as the Metal were the Men.
Truth, Modesty, and Shame, the World forsook :
Fraud, Avarice, and Force their places took.
Then Sails were spread, and the Depths were new.
Trees rudely hollow'd did the Waves sustain,
E'er Ships in Triumph plough'd the watry Plain.
Then Land-marks limited to each his Right :
For all before was common, as the Light.
Nor was the Ground alone requir'd to bear
Her annual Income to the Crook'd Share,
But greedy Mortals, rummaging her Store,
Digg'd from her Entrails first the precious Ore ;
which next to Hell the prudent Gods had laid ;
And that alluring Ill to sight displaid.
Thus cursed Steel and more accursed Gold
Gave mischief Birth and made that mischief bold ;
and double Death did wretched Man invade ;
By Steel assaulted, and by Gold betray'd.
Now (brandish'd Weapons glittering in their Hands)
Mankind is broken loose from moral Bands ;
No rights of Hospitality remain :
The Guest by him who harbour'd him is slain.
The Son in Law pursues the Father's Life.
The Wife her Husband murders, he the Wife,
The Step-Dame poison for the Son prepares ;
The Son inquires into his Father's years.
Faith flies, and Piety in Exile mourns ;
And Justice, here opprest, to Heav'n returns.

Jupiter destroys this race by a deluge which Deukalion and Pyrrha survive. On the advice of Deukalion's father, Prometheus, they had built a

boat in which they drifted for nine days until they ran aground on Mount Parnassus. Then they threw stones behind them, from which men arose The other beings owed their existence to spontaneous generation and to the action of the sun rays upon the prolific mud. The legend recalls the deluge lore of cuneiform inscriptions, the biblical story of Noah, and the Egyptian myth of the origin of the living beings.

The many gods become more and more shadowy. Nature, *melior natura,* which is called God, is the only ruler.

III

THE MOST BEAUTIFUL AND PROFOUND CREATION MYTHS

MANY civilised nations remained practically at the standpoint which we have just indicated.

Although Rome had attained a high degree of culture before the beginning of the Christian era, Ovid wrote on the origin of the Universe much as Hesiod had done seven hundred years previously. One might almost believe that the study of nature had not advanced in those centuries. Yet, we shall see, conceptions of the problem had matured in many thinkers and explorers, such as still excite the admiration of our age. But the fruit of those researches appears to have been reserved for the few initiated. Whoever addressed the public felt constrained, in the interests of the commonwealth, to pronounce opinions which had been sanctified by centuries and been incorporated in the tenets of the official religion. Most of the initiated probably had too poor an opinion of the results of the study of natural science ; Lucretius makes an exception. That the fruits of scientific

inquiries were not allowed to become the property of the masses, has probably contributed more than any other circumstance to the rapid overthrow of ancient culture by the invading barbarians.

It is, further, more than probable that there were thinkers among the Egyptian priests who had long ago risen from the primitive standpoint of Egyptian creation lore. The priests, however, kept this knowledge strictly for their own class, in order to rule the enslaved people by their superior knowledge.

But it happened about 1400 B.C. that an enlightened monarch, Amenhotep IV, introduced a reformation with the object of adapting the Egyptian religion to the advanced state of culture. He proceeded on decidedly radical lines. He proclaimed that the uncounted multitude of ancient gods was abolished, and that he acknowledged one god only, Aten, the Sun. He pulled down the ancient temples and removed from the old capital of Thebes, as it teemed with idols. But he had the imperious priesthood against himself, and the blind crowds followed their spiritual leaders. Thus it could come to pass that this violent eruption of truth disappeared, without leaving any trace, with the king's death, and that his successor and son-in-law, Ai, had to say : " I must bend my knees before gods, whom I despise."

THE LIFE OF THE UNIVERSE

The grand feature of the religion of Amenhotep —or Chut-en-Aten, " the glory of the Sun disc "— was that he proclaimed the Sun Nature's supreme head. It is the Sun which provides the energy for every movement on Earth—apart from the not very important tides. According to Laplace, all terrestrial matter has indeed been emitted by the Sun, if we disregard the relatively small masses which fell upon the Earth as meteorites. The Sun may be termed the " Origin of All Things," whether we think like the primitive races merely of terrestrial objects, or have the solar system in mind. In the following beautiful hymn to the Sun Deity, the god is addressed by two names, Re and Atum :

Adoration to Thee, Re, in the east, Atum in the west !
Thou risest, Thou risest, Thou shinest, Thou shinest
With a crown of splendour. Thou art the King of the Gods,
Of the Heavens, the Lord of the Earth.
It is Thou who created the Stars above, Men below,
Thou art the only God, who was always, from the beginning.
Thou made the Lands and Thou created the Nations.
Thou hast given us the Water, the firm Land, the Nile,
All the Waters, and thou hast granted Life to what is in the Waters.
Thou hast joined the chains of the Mountains and hast called forth Man and Earth.

In Laplace's system the Sun may be said to be, in the Egyptian sense, the creator of the most important stars, the planets. And as the planets

were themselves personified, we might call the Sun the only god from the beginning.

Zarathustra's (Zoroaster's) conception of the Universe reminds us of that of Amenhotep, which preceded it by one or two centuries. According to Zarathustra, infinite space, the Chaos of others, had been in existence for infinite ages, and with it the powers of light and of darkness. The god of light, Ormuzd, shaped out of pre-existing matter things in the following order, which it is instructive to compare with the order in which the Babylonians and Hebrews made things originate :

Ormuzd created :	Marduk created :	Elohim (Gen. i.) created :
1. The Amshaspands*	1. The Heavens.	1. The Heavens.
2. The Heavens.	2. The Heavenly Bodies.	2. The Earth.
3. Sun, Moon, and Stars.	3. The Earth.	3. Plants.
4. Fire.	4. Plants.	4. Heavenly Bodies.
5. Water.	5. Animals.	5. Animals.
6. Earth and Living Beings.	6. Man.	6. Man.

To the adherents of Zarathustra, the Sun, as the all-important light, was also the chief object of adoration, as Marduk, the Sun-god, was to the Babylonians. Many other nations, the Japanese, for instance, have instinctively passed from polytheism to the worship of the Sun.

* The Amshaspands or Amesha Spendas are the six highest deities next to Ormuzd, representing each an ethical conception.

Zarathustra's religion changed with time, and his Persian adherents split into many sects. The Zervanites, one of the most powerful of these sects, taught that eternal time, " zervane akerene," was the supreme principle, from which both the principle of Good (Ormuzd) and the principle of Evil (Ahriman) had sprung.

By amalgamation with islamitic and with gnostic elements the teaching of Zarathustra became modified into Ismailism, which is tinged in a philosophic-mystic shade. Behind the World there stands an inconceivable, nameless Being, the personification of Infinity. It has no attributes, nor can it be worshipped. From this Being spring, as a necessary natural consequence, a series of emanations : (1) the All-Reason ; (2) the All-Soul ; (3) shapeless Primary Matter ; (4) Space ; (5) Time ; and (6) the Material World, in which Man occupies the foremost position. This religion appears to assign to matter, space, and time a higher grade than to the shaped and therefore perceptible world. It is like the modern thesis, that matter, space, and time are infinite. The All-Soul also stands on the higher level ; it may signify the eternity of life.

According to Zarathustra's doctrine, Astvadereta will awaken the dead, and the state of beatitude will be restored. The Ismaelites saw in the Zoroastrian doctrines of resurrection and judgment merely similia indicating the periodic changes of

the Universe. This latter interpretation may be due to Hindu influences.

The ancient priest caste of the Hindus evolved in the course of ages a theory of eternity. It has its deep philosophical meaning, and we may understand it as the germ of the theory of the indestructibility of matter and of energy. The eternity principle is indispensable to modern cosmogonies. But as development is discernible in the Universe, we can only grasp eternity as periodical, ever-repeating evolution. The following narrative may show how the Indian philosophers imagined their cosmogony.

Manu (in the Vedic Hymns Manu is a kind of Noah, the Ancestor of all human beings) was once immersed in profound contemplation. Then the Maharishis approached, saluted him reverently, and spoke to him: "Lord, deign to expound to us, carefully and in the right order, the laws of the origin of all things and also of those which owe their existence to mixing. Thou alone, Master, knowest the foundation, the signification, and the consequences of those general laws, fundamental and inconceivable and unfathomable to common human understanding; for they are Veda." And the All-Powerful gave the following wise answer: "Listen. This world was sunk in darkness, intangible, without distinctive marks. Reason could not understand it, it could not be revealed, it was all-reposing in sleep. When the

solution (the Universe is imagined as a perfectly uniform solution) was approaching its completion, the Lord (Brahma), who is his own progenitor and incomprehensible to our senses, made perceptible the World by means of the five elements and of other primal substances. He illuminated it with the purest light, dispersed darkness, and created the development of Nature. He felt desire to let the things spring forth from himself. And thus he created first the waters and threw into them a seed. That seed grew into a golden egg, resplendent with the lustre of the thousand-rayed star, and out of it was born the Supreme Being, in the shape of the male Brahma, the origin of all things. After having reposed in this egg for one divine year (a little more than three billions of human years), the glorious Lord, by his own contemplation, split the egg in twain, and shaped out of it Heaven and Earth. Between them he placed the sea of air, the eight spheres of the Heavens (compare Fig. 6, page 78), and the infinite space for the water. After that the perishable world was created which emanates from the eternal world." In addition he created a multitude of gods and spirits and ages. The Glorious Being and with him all living beings pass through alternating periods of waking and reposing. A human year is equivalent to one spiritual day. Twelve thousand spiritual years, each comprising 360 terrestrial years, make up one divine period;

two thousand divine periods constitute one day of Brahma. During the second half of this day—of 8640 million years—Brahma and all life are asleep; when Brahma awakes, he satisfies his desire for creating. The periods of creation and of annihilation are infinite in number, and the Eternal Being repeats them as if at play.

The grandeur of this Hindu philosophy lies in its correct expression of the conception of eternity, which demands periodical changes in evolution. But the conception is pessimistic; the development of each period is a continuous recession, especially in moral respects.

This pessimistic principle, with which we meet also in Egyptian myths and in classical antiquity and its teaching of a first golden age, as well as in the Chaldæan legends of paradise and the fall of man by sin, is in direct contrast to the modern theory of evolution which has been built up on the study of Nature. Precursors of this modern view of evolution are also found in Egyptian myths and in Homer. We believe that man gradually rises to something higher. Only the strongest and fittest survive in the struggle for existence, and successive generations improve in vitality.

In the above quoted narrative we discern for the first time the distinctly expressed opinion that a mere thought or act of will may be the cause of work and of matter, without consumption of

any pre-existent energy or matter. In other words, a creation out of nothing is considered possible. This belief found many adherents ; the idea was preferred to the thought, which originally will have been common to all races, that the creation was merely a reshaping. From the scientific, as well as from the philosophic, point of view this idea that something may spring from nothing, is of course untenable (cp. page 2). It will be sufficient to refer in this connection to the unequivocal sentences of Spinoza and of Herbert Spencer. Spinoza says in the preface to the third part of his " Ethics " : " The laws and rules according to which everything takes place and everything is transformed, are always and everywhere the same." In his " Principles of Biology " (I, pages 336 and following) Spencer states : " Is it supposed that a new organism, when specially created, is created out of nothing ? If so, there is a supposed creation of matter ; and the creation of matter is inconceivable, implies the establishment of a relation in thought between something and nothing—a relation, of which one term is absent—an impossible relation. Is it supposed that the matter out of which the new organism consists is not created for the occasion, but is taken out of its pre-existent form and arranged into a new form ? " The creation of energy is quite as inconceivable as the creation of matter. " The belief in special creations of organism is a

belief that arose among men during the era of profoundest darkness." This last sentence may perhaps be slightly modified; the possibility of a creation out of nothing is only found in a relatively advanced stage of development.

It may appear striking that the old Scandinavians should have left the best elaborated creation saga. But we must bear in mind that the ancestors of the Norsemen had occupied their abodes in Scandinavia since the stone age, that is, for thousands of years probably, and that the finds from the Scandinavian bronze age indicate a high state of culture. Some of their ideas they took no doubt from classical antiquity, clothing them after their own fashion.

With the ancient Chaldæans and Egyptians, as well as with most primitive races, water was the essential primary element, contrasted with the solid earth. With the Scandinavians the warmth was the essential element, and its opposite the cold. Considering that heat is doubtless the most important physical agent, the Scandinavians deserve credit for the scientific truth of their conception, and it is indeed wonderful to observe, how beautifully this cosmogony adapts itself to our own ideas. Some features doubtlessly betray oriental sources or infiltration of classical opinions. But the intelligent interpretation of Nature's own ways is characteristic for the Scandinavian cosmogony.

In my story I follow Victor Rydberg's "Fädemas Gudasaga." The world, in which we live, is not of infinite existence. It has had a beginning and will have an end. When time dawned,

> Sand was not, nor sea,
> nor cool waves.
> the Earth was not
> nor Heaven above.

There was the bottomless abyss Ginnungagap, and in its northern portion the spring of cold, shrouding all in icy mists; for that reason the region was called Niflheim. In the south was the spring of warmth, Urd; between the two the spring of wisdom, Mimr's well. From Niflheim mist-grey waves of cold streamed out into space, meeting the warm currents from Urd. By their mixture arose the elements, from which the world, and later giants and gods took their origin. From the void space, there where Mimr's spring was situated, grew out of a seed the world-tree Yggdrasil, invisible to human eye, sending its roots to the three springs.

The grand characteristic of this saga is that it bases the inhabited world on sources of heat and cold, analogous to the suns and cosmic nebulæ. The inhabited world lies between the two sources, and its existence is dependent, as the modern conception would express it, upon the supply of heat from the suns, and its discharge towards the cold nebulæ.

The Norse legend takes up the common belief of the creation of the world out of the limbs of a dead body. A god, Odin (the Chaldæan Marduk), kills the giant Ymer (Tiamat) and shapes from his body Heaven and Earth, and from his blood the ocean. But here the Norse saga introduces an original modification. Ymer's limbs had first to be ground to dust, before they could bear living beings. The giant-mill was built for this purpose; it was driven by the water from the cold spring which a trough carried off into the ocean. That is a poetical description of the weathering process which disintegrates the solid rock by the action of frost and water. The giant-mill also turned the firmament with its fixed stars.

In the Babylonian legend a monster of the sea, Oannes, a fish body with human head, arms, and feet, rises from the waves to teach man arts and craft, and disappears again in the depth. His place is taken by the god of fire, Heimdal, whom the sparks engendered from the stones of the giant-mill. In the shape of a beautiful, delicate, fair-haired youth he comes in a boat to bring man the blessings of civilisation. He carries in his boat a grain-sheaf, implements, and weapons. He grows up, becomes the chief of the men, gives them his fire-drill and the fire, teaches them the runes and arts, tilling the ground, cattle breeding, forging, bread-baking, building, and other craft, as well as hunting and the art of defending themselves. He

establishes matrimony, the State, and religious rites. When, after a long and wise reign, Heimdal lies down to eternal rest, they find on the beach the same boat that had once brought him. The grateful people placed his body in the boat which the flowers of the hoar-frost had made beautiful, and they charged the boat with precious forged objects and gems. Impelled by invisible oars, as on its arrival, the boat shot out into the sea, and disappeared on the horizon. Heimdal landed in the realm of the gods, and was revived a radiant youth. His son Sköld-Borgar succeeded him as the chief of the people.

During Sköld-Borgar's time the world deteriorated, and when his rule was drawing to a close, Balder, the god of light, died. Then came the terrible Fimbul-winter, when glaciers and fields of ice covered the inhabited earth, and the crops of the still ice-free land impoverished. Famine broke out and drove men to dire crimes. It was the age of storm, of the axe and knife, and, sword in hand, the Norsemen attacked affiliated tribes, searching for lands further south. After a time the Fimbul-winter and ice passed away.

The saga depicts a deterioration of the climate and an ice age, forcing men to emigrate. No wonder that the Norsemen believed, that another Fimbul-winter would initiate the end of the world, the Ragnarök. On its approach the terrible state of lawlessness would return. The giants

from the land of frost would rush against the abode of the gods; men would die with cold, hunger, pestilence, and strife. The Sun would still continue in its journeys across the sky, but its splendour would grow faint. In the war between giants and gods many gods would be slain, and even the fire-god Heimdal would be mortally wounded. Then the Sun would be extinguished, the vault of Heaven split, the rocks which kept the fire of the depths imprisoned would burst, and Surtur's flames sweep over the battlefield. But a new, green world would arise from the terrible conflagration. The fire had not destroyed Hoddminne's grove near Mimr's well, and a few of the gods, as well as the human couple Lifthraser and Life would find shelter in the grove. The men return to the Earth. A new, blissful age begins that knows no cares, and the untilled ground yields abundant crops.

Classical and Christian traits may have modified this remarkable saga. What impresses us is the idea of the diminishing power of the Sun and the consequent extinction of life on Earth. The Sun (the gods) will then collide with the world of cold (the giants), the cosmic nebulæ and the extinct suns in it. The collision bursts the solid crust of the Earth and the internal fire, known from the Icelandic volcanoes, destroys the Earth. After a while, however, a new Earth will be formed, and life (the gods) will

once more descend from the immortal tree in space, Yggdrasil, down to the Earth.

In beauty and truth the Edda saga surpasses by far everything that other uncultured races imagined. No doubt, the first civilisation and, with it, the original elements of the creation myth came from abroad, probably from the Orient, across the sea ; the beautiful Heimdal saga suggests that. But no other creation lore approaches the Scandinavian saga in the faithfulness of its conceptions of Nature.

In the above lines I have attempted to sketch out the cosmical beliefs dating from ages in which direct physical observations were hardly known. Natural science then appears in the garb of myth ; when risen to a higher level it assumes the many-folded cloak of philosophy. Matters change when observations and experiences are collected. Then man begins to look for general rules, under which the cumbrous mass of data can be classed in simple, lucid form. Before experiences can become fruitful, they have to be systematised by the theorist. When the first, possibly inaccurate rules have been laid down, we may venture to predict events. The confirmation of those predictions will strengthen our rules and improve our knowledge.

It was first the knowledge of time that engaged the earnest attention of observing races. That knowledge suggested ideas concerning the nature

of the celestial bodies, which had to be studied in their analogies to terrestrial objects. Thus the elementary astronomical, physical, and chemical conceptions were gradually evolved. The eminent advocates, formerly unmentioned, of certain views were now quoted, and we thus arrive at a real historical review of the evolution of ideas.

In the following chapters we deal with the cosmogonies of historical times, as distinguished from the saga-ages. A sharp boundary line cannot, of course, be drawn.

IV

COSMOGONIES OF THE ANCIENT PHILOSOPHERS

BARBAROUS tribes did not feel the need of a time scale and had no reason to look for a measure of time. Hunting and fishing were their means of livelihood. When the chase failed and hunger pinched, they learnt to appreciate berries and edible roots. That food was only make-shift for the men, however. The women probably had often to be contented with such nourishment ; for the men will hardly have given them more than the abundance of game and fish. The tribes had to follow the game in its migrations, and the day's cares were enough for them. Matters did not change much, when man tried to tame and to keep beasts, with the object of securing a food supply. The cattle needed fresh grazing grounds which changed with the seasons, and the position of the camp of nomadic tribes depended upon the cattle, not upon the masters.

Conditions did change when the increasing population had to till the ground. Fixed quarters had to be chosen, and the fields had to be culti-

vated in certain seasons, if crops were to be reaped in due course. The changes of the seasons depended upon the positions of the Sun, and it was desirable to watch the Sun. It was soon noticed, however, that the rising and setting of certain stars in the various seasons was more easily observed. The regular changes of the Moon, reoccurring in short periods (of 29·53 days), will not have failed to attract attention; they furnished a measure for periods of moderate duration, and the Moon alone will have been the clock of the nomadic tribes in the earliest ages. The nomads wandered with their herds in the mild light of the Moon and avoided the burning rays of the Sun. Later on the Sun was worshipped as the ruler of the world, and the year was made dependent on the movements of both Sun and Moon. Since now the year comprises more than twelve synodic months, and less than thirteen, some years were given twelve lunar months, others thirteen months, and the resulting average length of the year was thus correct. The day was divided into six equal parts, each of sixty minutes; the Babylonian minute hence corresponded to four of our minutes, and the Sun traversed one degree on the sky in the course of one Babylonian minute.

The Chaldæans perceived that some of the stars, and some of the brightest, were less suitable than the others for the determination of the seasons. These irregular stars were called planets or wander-

ing stars; like Sun and Moon, they appear to wander from one constellation to another, whilst the other stars keep to their respective positions. Like Sun and Moon, the planets became objects of worship. The oldest regular stellar observations of the Chaldæans may go back four or five thousand years further than our Christian era. According to the Romans and Greeks those observations had indeed been conducted for several hundred thousand years. The astronomer Hipparchos speaks of observations for 270,000 years, Cicero even of 470,000 years—very arbitrary estimates, of course.

Kallisthenes collected such observations extending back to 2300 B.C. for Aristoteles. On their slabs of clay the Chaldæan priests noted, night by night, the position and brightness of the stars and the moments of their rising, setting and culmination. The movements of the fixed stars are so regular that their positions may be predicted with a very high degree of accuracy. The movements of the planets are not regular, but it was observed that the irregularities were periodical, the period of Venus being 8 years, and that of Jupiter 83 years. The positions of the planets having carefully been noted during those periods, consultation of the tables enabled the astronomers to predict in which constellations the planets would be found in future years. Real planetary ephemerides were compiled in advance, and some of these

have been preserved; one for the year 523 B.C. is, for instance, still in existence. The trajectory of the Sun through the zodiac is likewise very regular. It progresses every day by nearly one degree, and that was the reason why the Chaldæans divided the circle into 360°. When it was recognised that the Sun moved at a much faster rate in winter than in summer, this irregularity was allowed for by assuming that the Sun described an arc of 1·0159° in a winter day, and an arc of 0·9524° in a summer day. The most famous of the Babylonian astronomers, Kidinnu, effected a notable improvement in these calculations by introducing a different rate of solar movement for each month. Kidinnu lived at the beginning of the second century B.C., and conducted many remarkable observations; his tables on the movements of the Moon are particularly accurate. Striking regularities were also found in the relative movements of the Moon and Sun; their recognition was probably the results of observations extending over thousands of years. After 235 synodic Moon revolutions or 6939·69 days (or 19 solar years), the Moon will once more occupy almost exactly the same position with regard to Sun and Earth. An eclipse of the Moon, observed on a certain day, may therefore be predicted to recur after the elapse of 19 years, the so-called Metonic cycle. Evidence of the knowledge of this cycle was discovered by Kugler in

astronomical calculations of Babylonian origin, dating from the commencement of the fourth century B.C. That would be about fifty years after the Greek Meton had introduced the cycle in 432 B.C. The two discoveries were probably independent of one another, though there was intercourse between Babylon and Greece at that time, viâ Phœnicia apparently. Thales seems to have been of Phœnician origin. The astronomical knowledge of the Babylonians afterwards became familiar to the Alexandrian Greeks.

Prediction is also applicable to solar eclipses though not with quite the same reliability. Eclipses, especially of the Sun, do not fail to impress man and, in fact, all living creatures. The authority of the star-watching priests was hence greatly strengthened, when they learnt correctly to prophesy these phenomena. The astronomers must soon have recognised that eclipses depended upon the position of the Moon with respect to the Sun and Earth. They will also have understood, that it was the shadow of the Earth which darkened the Moon during a lunar eclipse. As this shadow was circular, they will have concluded that the Earth was round. And as this was always so, no matter which portion of the Earth was turned towards the Moon, it followed further, that the Earth must be round like a ball, not a round disc. These observations will thus have supplied a correct

idea of the shape of the Earth and of its relation to the Sun and Moon as celestial bodies. The Babylonian astronomer Seleucus (second century B.C.) knew that the Earth is spherical, and that it rotates about its axis. The Chaldæans probably carried out geodetic arc measurements. Achilles Tatios, a Greek writer living in Alexandria in the fifth century after Christ, relates that, according to the Chaldæans, a man, who could keep up a speed of thirty stadia (about five km.) per hour without resting, would want a year to travel round the world. That statement would make the circumference of the Earth 43,800 km., which is approximately correct.

The Chaldæans hardly advanced much further in their ideas concerning the Universe. The Babylonians very carefully tabulated the positions of the celestial bodies; but, unlike the Greeks, they did not speculate upon the structure of the Universe. This is the characteristic difference between oriental and occidental thought. The planets were regarded as gods and credited with more freedom of will than the stars, and their appearance was interpreted as a happy or unhappy foreboding for life and death, for inheritances, and for human projects. It was impossible to prevent the fulfilment of those omina; but their effects could be mitigated and, above all, delayed by prayer, sacrifice, and conjurations. How to achieve that, was only known to the priest

astrologers, and thus their power over the princes and the people became more and more firmly established. The belief in astrology kept the superstitious people in bondage throughout the Middle Ages and impeded scientific investigation, as it prevented the search for a natural explanation of natural phenomena.

In measuring time the Chaldæans made use of the water-clock, *clepsydra*, and of the sundial, *polos*, the latter a vertical rod fixed over a hemispherical concave base, divided into circles, whose radius was the length of the rod. In the water-clock water or some other liquid flows through a small aperture from a large receptacle, and the time is determined by weighing the escaped water. The polos served for fixing the north-south line (meridian), the position of the Sun in winter and summer, and the direction of the axis of the Universe, as well as the equinoxes. The finds of crystal lenses, made in the ruins of Mesopotamia, show that the Chaldæans were well up in optics; in other branches of science they do not appear to have excelled.

According to the Egyptian legends, the god Thot taught man astronomy, magic and prophecy, medicine, writing and drawing. The trajectory of the Sun through the thirty-six constellations of the Zodiac, each of which corresponded to one decade, was marked on tables which had, since remote days, been kept by the priests of the temple

of the Sun-god Ra. Later astronomers were also appointed for the temples of other gods; these astronomers, the "watchmen of the night," had to observe the heavens and to record their observations. They even drew star maps, some of which have been preserved together with their tables. The Egyptian year was divided into 12 months of 30 days. The year commenced in the beginning of August, and its length was corrected by the addition of 5 extra days to the end of the year. The still missing $5\frac{3}{4}$ hours were adjusted in various ways, partly with the aid of astronomical observations, especially of the Dog Star.

In a certain respect this chronology was superior to our own. All the months had the same length of 30 days, while our calendar is an arbitrary confusion of months ranging from 28 to 31 days. February, it may be remembered, had originally 30 days. One of these was cut off and added to July, in honour of Julius Cæsar. Augustus had equally to be honoured, and February was deprived of another day, which was added to August. Posterity would have regarded these honours in a different light.

The solar revolution does not exactly comprise 365 days, and the just-mentioned difficulties, caused by this non-agreement, became more noticeable as time advanced. Occasional readjustments were made in the calendar to make the Nile floods always fall in the beginning of the

year. This arbitrary procedure continued up to the age of the Ptolemies, when the leap year of 366 days was introduced. This modification of the calendar was later on adopted by Julius Cæsar, who acted in his reform of the calendar on the advice of the Græco-Egyptian astronomer Sosigenes of Alexandria.

The defects of the thus improved Roman or Julian calendar began to show in the course of centuries, and Pope Gregory XIII had the calendar once more reformed in 1582. The Gregorian calendar is correct within one day in 3000 years.

The star-watching priests of Egypt enjoyed an extraordinarily high authority. Their studies concerned not only astronomy, in which they hardly surpassed the Chaldæans, but also medicine and chemistry, sciences in which they excelled. Egyptian physicians were consulted by Asiatic rulers like the King of Bakhtan; later on the Kings of Persia sent to Egypt for medical advice. Homer praises the Egyptian medical men as the greatest experts of their time. Some of their prescriptions are still preserved; literal translations in Latin verses of their prescriptions and of their hygienic rules were taught in the Middle Ages at the famous school of medicine at Salerno, and some of these rules and medicines are still popular. On the whole their medicines seem to have resembled the nauseating mixtures which Chinese druggists still offer for sale.

The Egyptians had a great reputation as magicians and soothsayers. It was believed that the learned men of Egypt could, by pronouncing certain sacred formulæ, make the water of rivers return to their springs, arrest or accelerate the Sun on its course, and enliven waxen images of men and animals. They had access to the courts, where they held the office of "master of the secrets of heavens." They ranked with the chiefs of the body guards and with the privy councillors, the "masters of the secrets of the Royal House." Like them and as a sign of superiority over the ordinary court officials they kept their sandals on in the royal palaces, and they were privileged to kiss Pharaoh's knee, instead of his feet. Leopard skins, corresponding to the ermine of later periods, were the distinctive garment of these magnates.

The following story, taken from Maspero, may illustrate the wonderful feats which the people thought these learned men capable of performing. Cheops asked one of them: "Is it true, that you can fix a cut-off head on its trunk?" The question was answered in the affirmative, and Pharaoh ordered that a prisoner should be fetched to try the experiment. The astrologer gave the humane reply that it would be a pity to risk the experiment with a human being; an animal would do. They caught a goose, cut off its head, and placed the head on the one side of the room, the body

on the other. The priest pronounced his magic formula, and head and body of the goose began to move towards one another and united once more ; then the goose cackled. The experiment had, of course, to be repeated twice ; it succeeded completely with a pelican and then with a bull. The princes and Pharaoh himself often desired the Royal astrologer to instruct them in his science and magic.

In navigating upon the Mediterranean and the Red Sea the old Egyptians steered their course with the aid of the stars ; Homer tells us that Ulysses found his way from the island of Kalypso to Corfu by these means. On the whole, navigators will have kept close to the shores. But storms will have carried many a vessel out upon the open sea, and both the sailors and the people on shore must have noticed, that the surface of the sea seemed to be curved as if it formed part of a sphere.

Many scientists have shared the opinion of the Scottish astronomer Piazzi Smyth that the design of the great pyramid of Cheops, which was built about 3000 B.C., embodied knowledge that was the exclusive property of the most learned Egyptians of the time. The base of this pyramid—as also of others—forms an exact square, whose sides run almost perfectly east-west and north-south, with a deviation of 1 in 750 only. The pyramid lies almost under the 30th degree of northern

latitude, not more than 2 km. south of it. In the middle of the northern face is the entrance to a long, narrow passage which is inclined to the horizon at 30°, and therefore parallel to the rotational axis of the Earth. The passage thus points to the celestial pole, and the circumstance that the atmospheric refraction tends to raise the apparent position of the pole slightly rather perfects this coincidence. We cannot doubt therefore that the builders of the pyramid were guided by noteworthy astronomical and mathematical knowledge.

But Piazzi Smyth overrated their information. The height of the pyramid was originally 145 m. and the perimeter of the base was 931 m. The ratio of these two figures is 1 : 6·42. This is nearly the ratio 1 : 6·28 of the radius of a circle to its circumference, but too small by a little more than 2 per cent. Smyth was hardly justified in suggesting that the builders meant to reproduce, in the measures of the height and of the base length of their pyramid, the ratio of the radius to the circumference of a circle.

Egyptian science unfortunately was not allowed to become the property of the people. Otherwise the culture of this race upon which we gaze with admiration would have attained a still higher degree, and our own civilisation would indirectly have profited. When the early Greek culture flourished most, between 400 and 600 B.C., Egypt

was really the home of the highest art and intelligence, and men like Thales, Pythagoras, Demokritos, and Herodotos visited the land of the Nile to quench their thirst of knowledge. Later on, under the Ptolemies, Egyptian and Greek art and science amalgamated on the classical Egyptian soil, and Alexandria became the centre of learning.

It is related that Thales of Miletus, who lived from 640 to 550 B.C., predicted an eclipse of the Sun and made his reputation thereby. The art of performing astronomical calculations he had presumably acquired in Phœnicia, and thus indirectly from Babylon, or in Egypt. To that country points also his teaching that water is the primordial element of all things. Anaximandros (611 to 547 B.C.), perhaps a pupil of Thales, taught that an infinite number of cosmic bodies had been formed out of a chaotic mixture of the elements, of infinite expanse. Another philosopher, Anaximenes (about 500), who, like Thales, belonged to the so-called Ionian school, regarded the air as the primary element. The Earth was produced by condensation of the air, in the shape of a disc floating upon compressed air. The Sun, Moon, and stars were all discs and moved about the Earth. There is not a trace of Egyptian philosophy in these theses of Anaximenes.

In Pythagoras, who lived in the second half of the sixth century (about 560–490 B.C.), and his school we again find decided influences of Egyptian

learning. Pythagoras was born on the island of Samos, but he emigrated and settled at Croton in Southern Italy. Like his Egyptian masters, he endeavoured to pledge his trusted disciples to secrecy; but his pupils were less reserved than their Oriental fellows and they allowed the secrets to leak out. Unfortunately we have no direct, but only second- and third-hand records of the teachings of this school, and most of these are ascribed to Philolaos. According to this view, all things in the cosmos could be expressed by figures, and the relations between these figures were subject to a strict regularity which was called harmony, in analogy to the harmony of musical notes. The Universe was equally extended in all directions, and consequently a sphere. In the centre of the Universe was the central fire. People on the Earth could not see this fire, as they were living on the opposite side, but they saw the reflection of the fire in the Sun. Earth, Moon, Sun, and the planets (which later on were credited with atmospheres like the Earth) were all moving about the central fire. The Earth was round and turned about the fire once in 24 hours; in a certain sense it was thus turning about its axis in one day, while the Moon required one month, and the Sun one year for its rotation. These periods were pretty accurately known. If the Pythagoreans had replaced the central fire by the Sun, they would

have had a fairly correct notion of the solar system. The heavens of the fixed stars the Pythagoreans thought a vast hollow sphere, also rotating about the central fire. Since they made the Earth perform one revolution in one day, this former view appears not only superfluous, but quite inconsistent.

Gradually the ideas of the Pythagoreans gained in clearness. The physical causes of the phenomena were being investigated. Heraklitos of Ephesus (about 500 B.C.) taught that nothing was absolutely unchangeable. Empedokles (a Sicilian, about 450 B.C.) came to the conclusion, which modern science has re-acquired, that an origin from nothing (a creation) was as impossible as the destruction of anything material. All things were composed of the four elements—earth, air, fire, water. The apparent destruction of a body only signified that its composition, the proportion of its component constituents, had changed. The teacher of Perikles, Anaxagoras, who was born about 500 B.C. in Asia Minor and who settled in Athens after the wars with the Persians, extended this teaching to the Universe, for which he postulated eternity. The primary Chaos had meanwhile assumed a more definite shape; the Sun was a colossal, incandescent ball of iron; the stars were likewise incandescent, owing to their friction against the æther. Since the Athenians accorded divine honours to the stars, as we can read in

Plato and Aristoteles, Anaxagoras was accused of blasphemy on information laid by one of his pupils, Kleanthes, and he was thrown into prison. The intervention of his powerful protector Perikles saved him from the fate of Sokrates. Exercising wise caution, Anaxagoras went into voluntary exile and died, generally revered, at Lampsakos at the age of 72 years.

We obtain a peculiar impression of the highly eulogised intelligence and civilisation of the Athenians, when we read how one of their eminent sons after the other chose voluntary exile to escape cruel punishment, frequently death penalty, for his philosophical belief. Sokrates had to drink the poison cup, because he disdained to flee. Plato lived for twelve years abroad not to share the fate of his dead master, and was initiated into Pythagorean tenets in Italy. Aristoteles, a pupil of Plato, was charged with blasphemy by a priest of Demeter and condemned to death by the Areopagos ; he succeeded in escaping to Chalkis on the Island of Eubœa, where he died in exile, in his sixty-third year (322 B.C.). Diagoras, who had denied the existence of the Greek gods, was also condemned to death and died in exile ; the philosopher Protagoras was banished and his books were publicly burned ; and Prodikos, who asserted that the gods were personifications of natural forces, was executed—all this in Athens, the stronghold of liberty. Slavery

was very common, and it is a great pity that most of the parchments of those days were prepared by slaves who little understood what they were recording. It is not improbable that the philosophers intentionally clothed their ideas in obscure phrases, not to expose themselves to the persecution by the fanatical people.

After Empedokles and Anaxagoras followed Demokritos, the founder of the atomistic thesis of modern science. He was born at Abdera in Thrace, some forty years after the birth of Anaxagoras, about 460 or 470, and he died in his native town at a very high age. The large fortune that he had inherited he spent in travelling, and he says of himself that none of his contemporaries had seen so much of the world, lived in so different climates, and listened to so many philosophers. Not even the mathematicians of Egypt, among whom he had lived for five years, surpassed him in geometrical analysis and deduction. He was probably the greatest thinker of the classical age; we possess nothing but unimportant fragments of his numerous writings, however. He believed the atoms to be in continuous movement, eternal and indestructible. All substances were formed by the combination of atoms, and everything happened conforming to the invariable laws of Nature. The Sun of Demokritos was of immense size, and the Milky Way consisted of stars similar to the Sun. The number of universes

was infinite. They passed through slow changes of destruction and restoration.

Most of what we know of this philosopher has come down to us through the intermediation of Athenian and other philosophers who, like Aristoteles (385–323 B.C.), opposed these doctrines. Sokrates declared astronomy to be incomprehensible ; it was unwise to study it. Plato (428–347 B.C.) uttered the wish that the 72 books of Demokritos should be burned. Plato dealt with natural science from a teleological standpoint, which we can only regard as wrong in principle.

Philosophy was then being degraded to incomprehensible metaphysics. According to Aristoteles, to whom we owe most of our knowledge of antique science, the vault of the heavens is round, and the orbits of stars are circles, because " the heavens are a divine conformation and must have divine properties." The planets cannot move by themselves, since they have no organs of motion. He believed in the spherical shape of the Earth (chiefly on account of the round shadow seen during eclipses) and made the Earth the centre of the Universe ; but he denied its motion. The Earth was the oldest divine being within the heavens. Aristoteles was a man of the most varied and profound learning, and we can still study his voluminous writings. It is much to be regretted that he did not approach the natural philosophy of Demokritos with an open mind.

At this time the school of the Sophists exercised great influence at Athens. The Sophists proved all and everything without previous study. The writings of this type of philosophers were almost worshipped during the Middle Ages. Aristoteles was held infallible. His methods of deduction in natural philosophy impressed their fatal stamp upon the reasoning of the Middle Ages — the reader will remember the strange speculations of the scholastics—and his influence was still powerful a few centuries ago.

Natural science took a sounder development in Syracuse and Alexandria. Hicetas of Syracuse, Cicero tells us, maintained that the Heaven was standing still, while the Earth turned about its axis. We do not know anything further about him. All the more, however, of his great countryman Archimedes (287–212 B.C.), the great inventor and engineer, who established the theory of equilibrium in mechanics. He taught that a liquid in equilibrium would assume a spherical shape, and that it had a centre of gravity like the Earth ; for that reason the surface of the sea was curved, not plane.

The natural philosophers of Alexandria arrived at a clear conception of the shape of the Earth and its position in the Universe. Eudoxus of Knidos (409–356 B.C.), who founded a school in Athens, had taught in Egypt. He succeeded admirably in representing the movements of the

celestial bodies by means of revolving spheres. With Plato he supposed the Earth to be in the centre of the planetary system, and his views were taken up by Aristoteles. Eratosthenes (275–194 B.C.) observed in Alexandria the altitude of the Sun at the summer and winter solstices and deduced from these observations, that the distance between the two tropics made up $\frac{11}{83}$ of the circumference of the Earth (this value is too great by a little more than 1 per cent). By taking solar altitudes both at Alexandria and at Syene (in Upper Egypt) he determined the difference in the latitudes of the two spots at $\frac{1}{50}$ of the circumference of the globe (this figure is 15 per cent too small). The distance between the same two places he estimated from the time which a camel caravan required for this journey, and he calculated that the circumference of the Earth would be 250,000 stadia, 42,000 km., which is a good estimate. Aristoteles had spoken of 400,000 stadia, Archimedes of 300,000; we do not know for which reasons. Posidonios (born in Syria in 135, died in Rome 51 B.C.) measured the maximum altitude that the star Canopus attained in Alexandria; it was $7{\cdot}5^{\circ}$, while the star just grazed the horizon on the Island of Rhodes. The distance between Rhodes and Alexandria was variously estimated at 5000 or 3750 stadia; the combination of these astronomical and terrestrial observations yielded the figures 240,000 or 180,000

stadia (40,000 or 30,000 km.) for the circumference of the globe.

Aristarchos (born about 270 B.C.) attempted to determine the size of the Sun and of the Moon from observations of eclipses and of the position of the Moon when just half illuminated ; his value for the Moon diameter was 0·33 of that of the Earth (the correct figure is 0·27, so that he was not far out), and his Sun diameter 19·1 (the correct value is 108 terrestrial diameters ; here Aristarchos' estimate was far too low).

Archimedes, who was in close touch with the Alexandrian school, tells of Aristarchos : " He believes that the Sun and the fixed stars are stationary, while the Earth moves in a circle about the Sun which is in the centre of its orbit." In a book which has erroneously been ascribed to Plutarch (46–120 A.D.) we read that Greece should have accused Aristarchos of blasphemy ; for he taught that the Heaven was immovable, and that the Earth rotated about its axis, while at the same time moving about the Sun along the Zodiac. The fixed stars were said to be at an immense distance from the Sun.—This book estimates the distance of the Moon at 780,000 stadia (130,000 km. or 20 Earth radii), which is quite wrong ; but strangely enough the distance of the Sun almost correct at 804,000,000 stadia or 134,666,000 km. instead of 149,500,000 km. Hipparchos of Alexandria (190–125 B.C.), the most eminent antique

astronomer, gave the almost exact estimate of 59 Earth radii for the distance of the Moon; in the solar distance Hipparchos was very far out with his 1200 Earth radii. Posidonios measured the solar diameter with the aid of the water-clock, and arrived at the value of 28 minutes of arc; from that observation he deduced a length of 70 terrestrial diameters, which is fairly correct. He also connected the tidal phenomena with the Moon.

These facts fill us with admiration for the extraordinarily advanced astronomical knowledge of the Alexandrian Greeks. But there was no corresponding advance in other domains of natural science, particularly not in physics and chemistry. Aristarchos had clearly anticipated the Copernican system by two thousand years. But his teaching was lost; his contemporaries did not comprehend its truth. Ptolemæus (about A.D. 130) became the ruling authority on astronomy; he was also an eminent optician. In his book "Almagest" the Earth was the centre of the solar system, and planets and Sun, as well as the Moon, moved about it in epicycles (compare Fig. 6).

Then the Roman Empire spread, and science too suffered under its despotism. The Romans had no sense for science; they did not see beyond direct utility. "Their religion," F. A. Lange states in his "History of Materialism," "was deeply rooted in superstition, their whole State

life was cramped by superstitious rules. The inherited customs were upheld with obstinate rigidity; art and science little interested them,

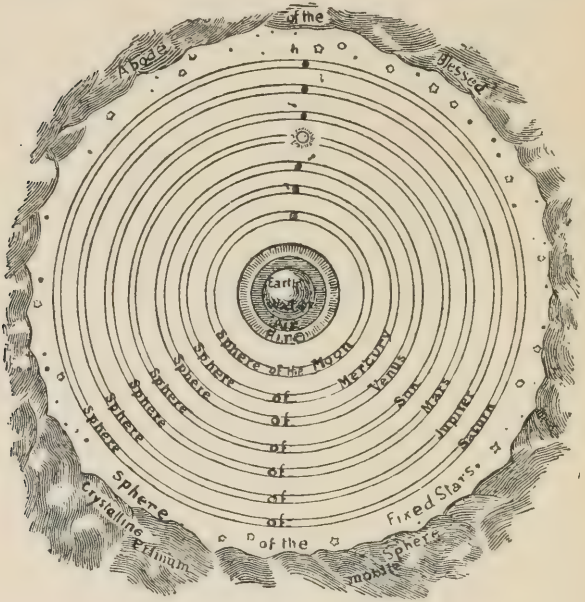


FIG. 6. The System of Ptolemæus.

contemplation of Nature still less. The practical aims of life were paramount. They were different to the Greeks, and the antipathy which their first contact with the Greeks called forth

lasted for centuries." Yet the art and literary treasures of conquered Greece were transported to Rome, and with them came members of the subjugated, but more highly cultured race. The better

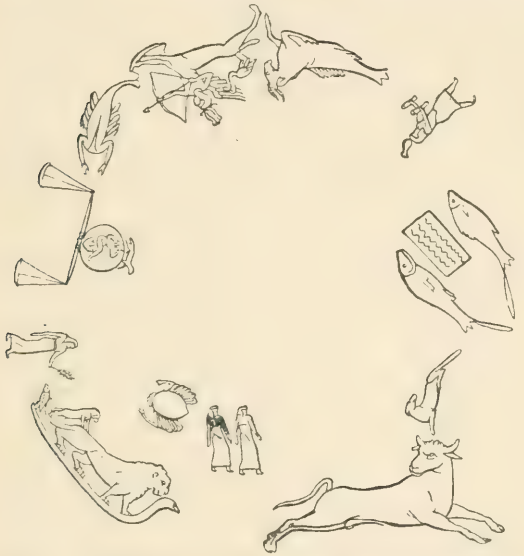


FIG. 7. The Zodiac of Denderah in Egypt, dating from the beginning of our era.

elements among the Romans fell under the spell of the superior intellect and strove to imitate the Greek masters. Thus arose the wonderful epic of Lucretius (99 to 55 B.C.), "De Natura Rerum,"

the eulogy of epicurean wisdom and of the philosophical teachings of Empedokles and Demokritos. It is noteworthy that this poem also discusses the properties of the magnet ; Lucretius probably took his information from Demokritos. Among the admirers of Greek philosophy, and of the great master Demokritos in particular, to whom we owe the preservation of many fragments of Greek learning, were Cicero (106–43 B.C.), a pupil of Posidonios, Pliny the Elder (A.D. 23–79), and Seneca (A.D. 12–66).

But the Romans stopped at imitation of their masters ; they did not produce anything original. Their philosophic training was merely a thin varnish. Their leaders committed the greatest barbarities. Cæsar, e.g., burned the library of Alexandria after the conquest of the city. His successors, the Cæsars, sank deeper and deeper into insane voluptuousness. The race of philosophers was soon extinct. The Christians had still less respect for science. Three hundred years after Cæsar they plundered, under Bishop Theophilos, the newly established library of Alexandria, and some 300 years later again the Caliph Omar burnt the books that were left. It is true that the Arabs afterwards rose to high culture. Science attracted them, and they collected the writings of the Alexandrian school, so far as still possible. But the sentiment of the people, misguided by intolerant priests, was not favourable to science ; the Koran

FIGS. 8 to 11. Four Constellations: Ophiuchus, the Great Bear, Orion, the Dragon, according to Al Sufi's star catalogue.

was considered infallible. Yet, on the whole the religion of the Moslim cannot be characterised as hostile to science. It is related that the Prophet once told his pupils: "The Last Day will come, when science will altogether have been extirpated." Harun al Rashid asked the Greek Emperors for gifts of philosophical literature. The request was willingly complied with, and the wise Caliph had the books translated, appointed learned men to study them, and sent others—no fewer than three hundred—out on journeys to acquire knowledge. His son Abdallah al Mamum collected classical manuscripts, and established libraries and schools for the education of his people. He had an arc measurement conducted in the desert of Singar near the Arabian Gulf in 827; the result was, one degree equal to 56·7 Arabian miles. Unfortunately we do not know the length of the Arabian mile; it was divided into 4000 ells of unknown length. Yet this determination of an arc appears to have surpassed those previously undertaken. He also had the inclination of the ecliptic to the equator determined; the value found was 28° 35′.

The most eminent astronomer of that period was Albatani (about 850–929), Governor of Syria. He determined the length of the year at 365 days 5 hours 46 minutes and 22 seconds (2 min. 24 sec. too short), and compiled excellent tables on the orbits of the planets. The Persian Abd al Rahman

al Sufi (903–986) lived half a century later. He catalogued 1022 stars, and this catalogue is valued far higher than that of Ptolemæus ; it ranks with the best that has been handed down to us from the old ages. His figure for the precession of the equinoxes is 1 degree in 66 years (the actual value is 71½ years).

Before this time already Dchafar al Sofi (702–756) of Mesopotamia had made the high school of Seville, at which he taught, famous as a centre of chemical science.

The power of the Caliphs of Bagdad declined about a hundred years after Al Mamum, and Cordova in Spain became the great seat of Arabian culture. Hakem II is said to have collected a library of 600,000 volumes at Cordova (about 961), probably an exaggerated figure. The great Arabian astronomer Ibn Junis belongs to the same period. He measured time with the aid of the pendulum, 600 years before Galilei, and he also compiled famous astronomical tables. A contemporary of his, Alhazen, is the author of a grand book on optics, in which he is said to have far surpassed all his precursors in this science. After Cordova was conquered back by the Spaniards in 1236, the library and the high school declined, and a centre of civilisation decayed, at which many Christians had sought inspiration and instruction.

When we inquire into the sources of ancient

civilisation and learning, we feel inclined to turn to China. The great Chinese thinkers have, however, not occupied themselves much with cosmogony. Confucius, who lived from 551 to 478 before Christ, states that he merely collected the ancient wisdom. He confined himself to morals, and he intentionally refrained from dwelling upon unpractical problems such as the origin of the world. We find a little more in the teachings of Laotse, born 604 B.C., the founder of the Tao-religion. It is difficult to explain what Tao really is. According to Suzuki, who has recently published a compendium of ancient Chinese philosophy, "Tao is not only the form-giving principle of the Universe; it seems also to stand for the primary matter, a *thing of chaotic composition which existed before Heaven and Earth.*" These last words are a quotation from the 25th chapter of the book "Tao Te King," by Laotse. Tao signifies "the way," yet not only the way, but also "the wanderer." It is the infinite path on which everything alive and lifeless wanders. It did not arise from any other being; it is itself the eternal Being, the All and yet Nothing, the cause and origin of all things, of Heaven and Earth. Laotse says: "How deep and mysterious is Tao, the origin of All, how still and clear is Tao, a conception that appears eternal. I do not know, whose son Tao is; it seems, that he existed before God (Ti)." "Heaven and Earth are indestructible,

for they have not engendered themselves, and they do not exist for their own sake." Sometimes Tao is called the secret of the secrets. This argument for the eternity of Heaven and Earth is very peculiar; from the explanation offered, that they have not arisen out of themselves, one might rather conclude, that they could be destroyed.

A Taoist, Liehtze, of the fifth century before Christ writes: "In the beginning there was Chaos, an inorganised mass. It was a mixture capable of developing into form, spirit, and substance." The same philosopher relates the following story of himself: "A man in the land of Chi was so troubled by the thought that Heaven and Earth might break up, and that he himself might perish thereby, that he could neither eat nor sleep. A friend came to him and consoled him with the following words: 'Heaven and Earth are nothing but condensed pneuma, and Sun, Moon and stars are merely luminous masses in this pneuma. Even if they should fall down, they could not cause any damage.' Both were satisfied. But a man named Chang-Tutze refused to accept this consolation; Heaven and Earth, he thought, would some day break into pieces. When this was reported to Liehtze, he laughed and said: 'It is just as great a mistake to assert that Heaven and Earth will break up, as to deny it; we have no means to decide the question. Whether that happen or not, does not concern me.' Suzuki himself remarks:

'The Chinese are not speculative like the Greeks and the Hindus. They never lose sight of the practical and ethical aspect of matters. They would laugh at those star-gazers whose feet are significantly resting on Earth.' On the whole this view of existence resembles that of the Romans, and in Confucius these characteristic features appear crystallised.

We may pass over these philosophical hazes. They only demonstrate the incapacity of agnostic abstract meditation to solve the cosmic problems.

Astronomers held appointments also at the Chinese temples. They had to watch the stars and to predict eclipses. It does not appear that they pursued the study of astronomy as a science, and they probably did not advance further than the old Chaldæans.

The Chinese of our age and the races who have adopted the religion of Mahomet regard matters which are not of direct public or private utility with a certain indifference which does not favour the progress of science. The reply, which the Turkish Kadi Imaum Ali Zadé gave to an astronomer from the Occident, may be quoted as characteristic. According to Proctor, Ali Zadé answered somewhat as follows: "Do not look for things which do not concern you. You came to us, we welcomed you; now depart in peace. You have indeed spoken many words, and no harm has been done; for there is one who speaks, and

another who listens. After the manner of your people, you have wandered from place to place, until you no longer feel happy and contented anywhere. Listen, my son! There is no wisdom other than the belief in God. He created the world. Is it for us to compete with Him and to dare to penetrate into the secrets of His creation? Shall we say: Look at this star, how it turns about another star, and look at that other star with a tail which will return to us in so many years? Be done with it! He, from whose hand the star came, will guide and direct it. I praise God that I do not strive after what I do not need. You are wise in things, about which I do not trouble my head."

That is the specifically Oriental maxim. We Occidentals have different views, fortunately. And the scientific spirit of the Arabs of the Middle Ages, whom we have to thank that the scientific treasures of antiquity did not perish, is well expressed in the following words of the greatest of Arabian physicists, Ibn al Haitam or Alhazen (about A.D. 1000): "From my earliest youth I have studied the opinions of men on matters of truth. Every sect clings to its opinion which the others condemn. I could not but doubt them all; for there is only one truth. I began to search for the sources of that which is true, and all my longing and aspiring had that one object, to find the essence of things. And

so I experienced what Galenus described in the seventh book of his medical art. I looked down upon the simple people and did not trouble about them (about their beliefs), but strove incessantly after truth and knowledge, and the conviction grew in me, that nothing better than this can be granted in this world." If we disregard the unfortunate contempt of the masses, so characteristic for those ages, we feel that the Arabian scholar and the modern scientist are in perfect accord. From the tenor of the utterances of Ali Zadé and of Alhazen, however, we understand why islamitic culture, which throve so wonderfully in the time of Alhazen, is no longer able to develop strong, healthy shoots.

V

DAWN OF MODERN AGES
MULTIPLICITY OF THE INHABITED WORLDS

THE Romans had little interest for science, especially for purely theoretical questions. They contented themselves with the study of Greek manuscripts and with commenting upon them. The rapid decay of the nation during the empire extinguished this already feeble scientific interest almost completely. No wonder, therefore, that with the fall of the Roman empire very little scientific interest was transplanted over to its conquerors, the Germanic tribes. We notice, however, that King Theodorich I (475–526) had a very high regard for science and was in intimate relations with the philosopher Boëthius. Charlemagne too endeavoured to promote literary activity as far as he could. In his time there lived in the famous monastery of Fulda a learned monk, Rhabanus Maurus. He compiled a kind of Encyclopædia which gives us an idea of the intellectual standpoint of those days in Western Europe : " All bodies consist of atoms. The Earth lies like a disc in the centre of the world, washed by the

floods of the ocean. About its centre as axis turns the Heaven."

Of the few learned men of the Middle Ages the Franciscan monk Roger Bacon (1214–94) may be singled out as standing far above his own time. He possessed extraordinary knowledge, especially of optics, and he foresaw the construction of the telescope. Unusually free of prejudices and far in advance of his own time was the German ecclesiast Nicholas de Cusa or Cusanus (born at Cues, near Trier, in 1401, died as cardinal at Todi in 1464). He declared the Earth to be an almost spherical star rotating about its own axis, shining with borrowed light, larger than the Moon, smaller than the Sun, and not standing still in space. Other stars were inhabited as well. Bodies were not destroyed ; they only changed their form.

The giant genius Leonardo da Vinci (1452–1519) held similar opinions. The Earth, as seen from the Moon, would in his opinion look as the Moon appeared to us. The Earth was neither in the centre of the Sun's orbit, nor in the centre of the Universe. It rotated about its own axis. With Nicholas de Cusa he shared the belief that the Earth consisted of the same kind of matter as the other planets, and not of some coarser stuff, as Aristoteles had taught and Tycho Brahe taught later. Leonardo had a clear conception of gravitation. If the earth were to burst into several pieces, he

said, those pieces would fall back to their common centre and would oscillate about it, to and fro, until, after several collisions, a new state of equilibrium would have been reached. One of the most remarkable of his ingenious expositions is his theory of combustion, according to which air is consumed during combustion, and animals cannot live in an air which is no longer capable of sustaining combustion. Leonardo was an engineer of extraordinary eminence, eminent in particular in hydraulic engineering. His canals are still in existence and admired by the present age. We owe to him wonderful theoretical researches concerning hydrostatics, statics, aerostatics, perspective, and the theories of waves and of colours. Everybody knows him as one of the greatest painters and sculptors of all ages, and he was in addition an expert on fortification and a bellettrist.

This powerful personality was of quite a different type to the mediæval monks. A new time had come. Before Leonardo was born the art of printing had been invented. Columbus had discovered America. The Renaissance had established itself with exuberant force. No reaction against the reformation of the Church had yet barred the general freedom of thought. Cusanus and Da Vinci were permitted to express, free and unimpeded, opinions which agreed with the teachings of Aristarchos-Copernicus except in so far that

they did not make the Earth turn about the Sun. The one man became a cardinal, the other enjoyed the favour of the most powerful princes. Leonardo died in Amboise in France, whither he had been called by the art-loving Francis the First. The magnificent popes rivalled the dukes of Milan, Ferrara, Mantua, Naples, and, above all, of

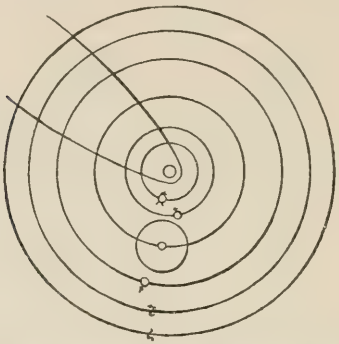


FIG. 12. The Copernican System, showing orbit of a comet. Compare Fig. 13, which represents our present views.

Florence, in promoting and protecting the arts and science. Sixtus V had the splendid library of the Vatican built and stocked. The age was ripe for further progress which the incipient reaction—headed by the terrible Inquisition—in vain attempted to check.

It was the study of the Alexandrian Ptolemæus' Great Syntax, a report on the astronomy

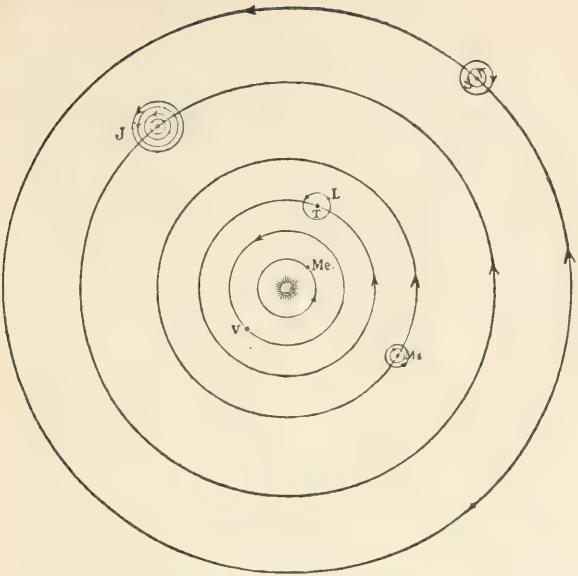


FIG. 13. Diagram indicating the movements of the planets and of their moons as appearing from a remote point to the north of the centre of the Sun. The disc in the centre is the Sun. Then come Mercury (Me), Venus (V), the Earth (T), with its Moon ; further out Mars (Ms) with two and Jupiter (J) with the four moons discovered by Galilei. Four other moons have since been discovered which circulate about Jupiter. All these celestial bodies (except the eighth moon of Jupiter) move in the normal sense, as indicated by the arrows, that is to say, in the opposite direction to the hands of a watch. Furthest out in the diagram appears Saturn (S) with nine normal moons (only one of which has been marked in the diagram) and one retrograde moon, Phœbe, discovered in 1898 by Pickering. To these are to be added the two planets Uranus and Neptune, discovered respectively by Herschel and Leverrier, which are two and more than three times further removed from the Sun than Saturn. Uranus has four moons, whose orbits are almost at right angles to the ecliptic, and which are even faintly retrograde. Neptune has one retrograde moon. Both these planets themselves, however, move in the normal direction, together with the large number of small planets, whose orbits lie between those of Mars and of Jupiter.

of his age (the second century after Christ), as well as his own observations, which induced Copernicus (1473–1543), a canon of German descent of Frauenburg, born in Thorn on the Vistula, to offer his system as a hypothesis. The treatise* in which he exposed his hypothesis, only appeared in the year of his death. He thereby escaped the fate which later on befell his zealous adherent Giordano Bruno, a Dominican monk from Nola in Italy.

Expelled from his country on account of his convictions, Bruno defended the Copernican doctrines when travelling through the chief countries of Europe and also uttered the opinion, that the fixed stars were surrounded by planets inhabited like our Earth. Bruno violently attacked the astrological superstition, which was impeding the progress of science, that the stars, and not the Sun alone, should exercise a powerful influence upon Nature and upon man. According to Bruno's views the celestial bodies float in an infinite, fluid, transparent sea of æther. On account of these doctrines, as well as on account of his assertion, that Moses had performed his miracles by natural means, he was arrested in Venice and condemned to die at the stake.

* "De Revolutionibus Orbium Celestium Libri VI." Copernicus had studied in Italy; his views were known to high dignitaries. But the publication of his book took place without his knowledge, when he was lying on his deathbed.—H.B.

The sentence was carried out on the 17th February, 1600, when Bruno was 52 years of age. The same spirit prevailed in those days that had once demanded victims in Athens ; only people were still more cruel and barbarous. Bruno's main efforts had been directed towards breaking the detrimental influence which the philosophy of Aristoteles had been exercising upon scientific ideas.

We may say that with this last great terrible triumph of the Inquisition the olden days came to an end. For the discoveries of Kepler, and especially of Galilei, advanced our knowledge far beyond the scope of the old age.

The system of Copernicus is frequently explained, as if it had been entirely independent of antique influences. How little justified this is, we learn from the following words of his own : " After having meditated on the uncertainty of the mathematical theses respecting the calculations of the circular movements of the spheres, I began to feel disgusted, that the philosophers, who had so assiduously studied the most insignificant features of these movements, had had no sure base for the movements of the universal machine which has been built, for our sake, by the best and the most lawful of all masters. I therefore took pains to re-read all the books of the philosophers upon which I could lay my hands in order to search, whether or not somebody had given expression to the idea, that the celestial bodies might have other

movements than those taught in the schools of mathematical science. Then I found first in Cicero that Nicetus (Hicetas) had firmly believed that the Earth must be moving. Later on I discovered also in Plutarchus that some others had been of the same opinion. I quote his words here to make them known : ' Others, however, believe that the Earth is moving. Thus Philolaos, the Pythagoræan, says that the Earth moved about the fire in an oblique circle, similarly to Sun and Moon. Heraklid of Pontus and Ekphantus, the Pythagoræan, do not stipulate a progressive movement ; yet they think that the Earth moves after the fashion of a wheel, between Occident and Orient, about its own centre.' Having learnt this I began to cogitate on the mobility of the Earth, and although this seemed to be contradictory to our experience, I yet persevered, because I knew that liberty had been granted to others before me to assume arbitrary circular movements for the purpose of deducing the stellar phenomena." Like Aristarchos, Copernicus considered the orbit of the Earth as very small by comparison with the distance of the fixed stars.

A few years after the death of Copernicus, Tyge (Tycho) Brahe was born in Schonen (1546). The sight of a total solar eclipse made a deep impression upon him and instilled the youth with a burning zeal for the study of astronomy. He conducted a very large series of extremely care-

ful measurements, chiefly in the observatory of Uranienburg on the island of Hven, observations which later on formed the basis of the work of his collaborator and successor Kepler, and which induced Bessel to call Tycho the King of the astronomers. Tycho again placed the Earth in the centre of our planetary system. About the Earth there were circulating Sun and Moon, and further all the planets. The fixed stars were attached to a spherical shell which was slowly revolving. The Earth completed one evolution in twenty-four hours. How strongly Tycho was affected by the prejudices of his time, we recognise from the fact, that after he lost the tip of his nose in a duel, he consoled himself with the conviction, that the stars had predicted this event in the hour of his birth. It is likewise characteristic for his frame of mind, that he considered the Earth to be of coarser stuff than the Sun and the planets, and that it should for that reason be in the centre of the planetary system. That the system of Copernicus was far preferable to the system of Tycho "because it was so much simpler and clearer," had already been emphasised by Descartes. Tycho's example shows that even the most intense application and the keenest power of observation will achieve relatively little success, if not coupled with a clear and unprejudiced grasp of theoretical questions. Tycho died at Prague in the year 1601.

It was reserved to Kepler (1571–1630) to draw the conclusions from the observations of Tycho. He demonstrated that the planets moved in ellipses about the Sun, and he deduced the laws connecting their velocities with their distances from

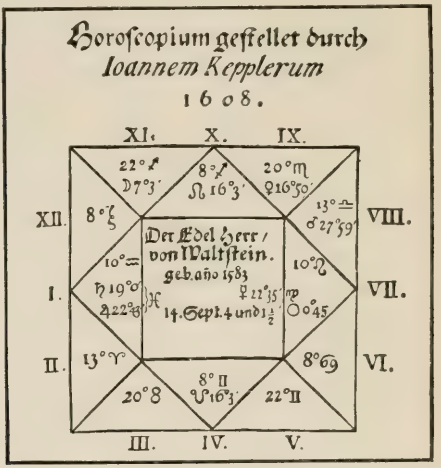


Fig. 14. Wallenstein's Horoscope, drawn up by Kepler.

the Sun. A characteristic feature should be mentioned. Kepler refused finally to perform any astrological calculations for the all-powerful Wallenstein, whose horoscope he had himself drawn up (Fig. 14). Yet he attempted to read his own fate and the fates of his children in the constellations of their

birthdays. Kepler hailed from a Protestant family and he had to suffer for his religion.

For the first time since Aristarchos, really important progress in our knowledge of the heavens had been made by Kepler. It was further strengthened by the discoveries of the great Galilei (1564–1642). Galilei, who corresponded with Kepler, says in a letter of the year 1597, that he had long been an adherent of the Copernican system. In 1604 he heard about the discovery of the telescope in Holland. He constructed one himself, and he enjoyed the full approval of the mighty men of his time. He began to explore the heavens and he observed a great many stars which had not been visible to the naked eye. The planets appeared like luminous discs. In 1610 he studied Jupiter and discovered the four large moons of the planet, of which those nearest the planet moved about it with greater velocities than those further remote, just as the planets did with regard to the Sun. He saw in these motions of the moons—which in honour of the princely family then reigning in Tuscany he called the Medicean Stars—a direct support of the views of Copernicus. He further noticed that Saturn changed its appearance—owing to the different positions of its rings—and that Venus—Mercury behaves in the same way—appeared as a crescent like the Moon. He even discovered the sun-spots in 1611, and he rightly concluded from their motions, that

the Sun must be turning about its own axis. All these discoveries were in sharp opposition to the views of Aristoteles as then taught in all the ecclesiastical schools. Galilei therefore thought it advisable to repair to Rome in order personally to convince his opponents. But as they could not refute him by the strength of their science, they asserted, that his doctrines contradicted the infallible Holy Scripture.

Only now, in 1613, Galilei proclaimed himself publicly an adherent of Copernicus in a book on the sun-spots. The ecclesiastical authorities did not at once proceed against him. In 1614, the Sacred Congregation decreed that the thesis of Copernicus of the double movement of the Earth was in contradiction to the Bible. Yet it was permitted to mention the Copernican doctrine as a hypothesis which might be applied in scientific arguments; but it was forbidden to proclaim it as truth.

Such a thing would be inconceivable in our days. In those days it was quite normal. One simply asserted that one did not believe, what one maintained. Everybody knew all the same, that one did believe it. The following public declaration which Descartes (1596–1650) made thirty years later (1644) is very characteristic: "There can be no doubt that the world was created in the beginning in all its totality, and that Sun, Earth, Moon, and stars originated at that time, that

there were on the Earth not only seeds of plants, but the plants themselves, and that Adam and Eve were not born as little children, but as grown-up people. Thus teaches the Christian faith, and our intelligence easily convinces us of the fact. Nevertheless it is more expedient, when we wish to understand the nature of plants and of men, to cogitate, how they may gradually have developed from seeds, than to consider them such as they have gone forth from the hand of the Creator. If we should be able to imagine some very simple and easily intelligible principles, by whose aid we could prove, that the stars, the Earth, and everything we perceive in this Universe could possibly have arisen from seeds, we shall much better understand them, than if we described them merely as they are now, although we really know that they have arisen in the manner just indicated. Since I now think to have arrived at such principles, I will briefly expound them here."

In this strange manner it was necessary to try to circumvent the numberless reefs of the Inquisition which never tired of tracing new contradictions between the newer opinions and the orthodox biblical dogmas. Galilei kept silent for seven years. Afterwards he became involved in a controversy with the Jesuit father Grassi, who quite correctly considered the comets to be cosmical bodies, whilst Galilei had adhered to the

old opinion that they were terrestrial. The Jesuits finally succeeded in accusing Galilei. He had to travel to Rome, in 1633, in order to defend himself before the tribunal of the Inquisition, although he was worn down with age and illness. He attempted by every means possible to avoid disputable tenets, but he was finally condemned to ignominious imprisonment and further forced to abjure the doctrine of the movement of the Earth. The writings of Copernicus, Kepler, and Galilei concerning the relation of the Earth to the solar system were subsequently interdicted by the Holy Congregation, and remained so until the year 1835.

Galilei explained in his writings that Pythagoras and Aristarchos had taught that the Earth was moving about the Sun. Galilei developed the theory of motion and he demonstrated that a body in motion upon which some force was acting would undergo an alteration in its movement ; when no force was acting, the movement would continue unchanged. Instead of supposing with Aristoteles that the air, which rushed in from behind a falling body, would accelerate the motion of the body, Galilei demonstrated that this air could only be an impediment to the movement of falling bodies.

The opposition of the Church against the system of Copernicus was, however, in vain. Descartes did not hesitate one moment to accept the opinions of Copernicus. Of course, he made enemies by

doing so, but he found safety in the Protestant countries Holland and Sweden. Unfortunately he succumbed to illness soon after having come to Sweden. According to Copernicus, all the planets, if regarded from the north pole of the Sun, move from right to left. In the same direction circulate : our Moon about the Earth, Galilei's Moons of Jupiter about their planet, and the sun-spots about the Sun. Further, they all travel approximately in the same plane of the ecliptic. In explanation of this regularity Descartes assumed with Giordano Bruno a kind of sea of æther in which the planets were floating. Descartes supposed this æther to be in vortex motion about the Sun as a centre, and that the planets were seized by this movement and driven around in almost circular orbits, like the dry leaves in a whirlwind. This view is certainly far superior to Kepler's opinion, according to which the planets were guided in their orbits by angles. As regards the comets, which do not behave like the planets, Descartes states that they are real cosmic bodies which move outside Saturn. As, however, Tycho Brahe had said, that his observations proved the comets to move indeed outside the orbit of the Moon, but frequently not in greater distances than those of Venus and Mercury, Descartes declared that those observations were not sufficiently reliable to justify Tycho's conclusion.

In a letter addressed to Morus, Descartes says :

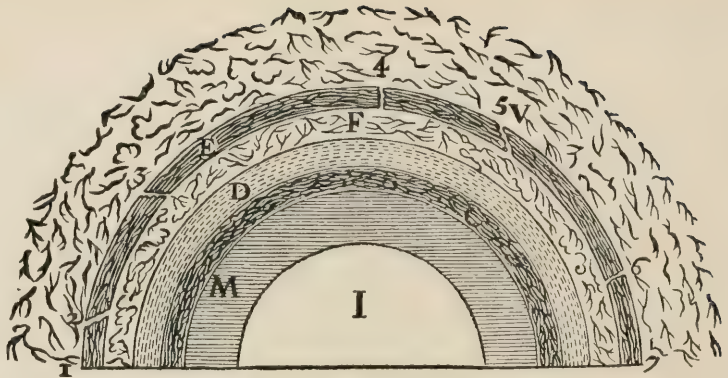
"Our mind cannot conceive the idea that the Universe should have a limit. Hence we say, that its extension is infinite. But from this infinity of space does not result the infinity of time. Though the Universe must be without end, yet theologists do not maintain that it must have existed for eternal ages." According to Descartes, the world is filled with matter; therefore everything must travel in circular closed paths. God has created matter and its movement. There are three elements in the Universe: out of the first, the luminous element, Sun and fixed stars have been made; out of the second, the transparent, consists the Heaven; and out of the third, the dark, opaque and reflecting, consist the planets and the comets. The first element is composed of the smallest particles, the third of the coarsest particles. In the beginning matter was distributed as uniformly as possible. Movement induced closed orbits about centres in which the luminous matter was collected, whilst the second and the third matter was whirling round. Of the dark bodies some possessed so powerful a movement, they were of so great mass and had drifted so far away from the centre of the vortex, that no force could retain them. These bodies have passed from vortex to vortex, and such are the comets. Bodies of smaller mass and of smaller velocity associated with the particles of the second element which were endowed with the same centri-

fugal force; these are the planets. Particles of the smallest mass penetrated furthest into the interior. By a movement of other particles, which does not quite resemble that of the planets, the latter are given a rotation from west to east.

Heat is due to the movements of the smallest particles. It may be produced by the solar rays falling upon material particles and by other means. The heat acts upon our sensations. By an increase in the spots a sun or a star may gradually be obscured, and inversely it may become brighter by a dispersion of the spots. Owing to this change in the intensity of the spots the luminosity of a star may increase or decrease. This explanation of the change of luminosity of different stars is still accepted by many astronomers of our days.

It may occur that the vortex about a star, which consists of a rotational movement of particles of the first and the second orders, is absorbed by adjoining vortices. Then the central star of this vortex will itself be carried away and drawn into another vortex, in which it becomes a comet or planet.

This transition from the stellar stage to the planetary stage Descartes has more fully explained in his description of the Earth. The Earth was at first a sun, surrounded by a powerful vortex consisting of the first-order element. Gradually it became covered with spots, until the spots



FIGS. 15 and 16. Diagrammatic section through half of the Earth, according to Descartes. I is the interior of the Earth, which consists of the same matter as the Sun. In the beginning the whole Earth was composed of this kind of matter. The matter surrounded itself with a crust M of denser particles corresponding to the sun-spots. The Earth therefore ceased to be luminous, became a planet, and was drawn into the solar vortex. Under the influence of the solar rays, there were separated air F and water D, and finally a solid crust of stones, clay and sand corresponding to our present Earth crust. This crust burst at the points 2, 3, 4, and collapsed; the resulting state of affairs is depicted in the lower diagram. Water broke forth, as indicated in the right and left portions of the diagram, and formed the ocean. On other spots, as at 1 and 4, mountains arose. Part of the air was kept enclosed under the mountains and under the solid crust of the earth, e.g. at F.

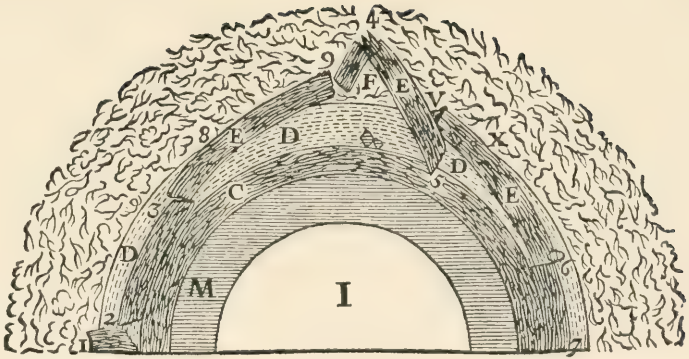


FIG. 16.

consolidated to a coherent crust. The glow of the terrestrial surface was now extinct. No more particles could be sent out to the remote portions of the vortex, which therefore gradually ceased to exist. But particles penetrated into this domain from adjoining vortices; previously they had been repelled by the particles which the incandescent Earth emitted. By these means the extinct Earth was drawn into the solar vortex near by and became a planet. The core of the Earth is still at white heat and is surrounded by a solid crust, the particles of the third order. There are in this crust strata of air and of water which are covered by the solid crust (Figs. 15, 16). Occasionally fractures occur, and fragments of the crust fall into the water below, which is then pressed up to the surface and forms the ocean, whilst the fractured crust becomes the material of mountains. Water also flows in the veins of the solid earth. In a more extended form these views were later expounded by Burnet (1681).

This briefly is Descartes' conception of the Universe. The fixed stars, which are centres of vortices grouped about the solar system, are at such great distances, that their positions relatively to the Earth are not noticeably changed by the movement of the Earth.

The science of chemistry was still very backward in that age. It was believed that the different properties were due to the shape of the smallest

particles. With truly philosophical thoroughness Descartes describes, how the different properties could be deduced by the assumption that the particles were large or small, light or heavy, round- or sharp-cornered, oval- or disc-shaped, ramified or flat. The prolix exposition of all these things has greatly impaired the clearness of his system.

Newton's great contemporary and rival Leibniz (1646–1716) has given, in his book "Protogæa," which was published in 1683 in the scientific journal "Acta Eruditorum," an exposition of the development of our Earth, which agrees in many points with what we believe at present. It was generally believed at that time, as the Norsemen had already done, that the Earth would once perish by fire; that will probably be its fate in a collision between the Sun and some other cosmic body. Leibniz starts like Descartes from an initial stage of high incandescence. This diminished—Leibniz says, from dearth of fuel—and the Earth surrounded itself with a crust; while the water, which formerly had been gaseous, was condensed at a later period. The glassy crust formed sand and, by reaction with the water and salts, the other strata. The sea had originally covered the whole Earth; hence we find old shells everywhere all over the globe. The surface became irregular, caving-in in places, and the deepest portions of the caves were occupied by the sea.

The famous Dane Steno (1631–1686), whose merits were only in 1831 rescued from oblivion by Elie de Beaumont, had the opinion that the horizontal strata, especially when they contained fossils of water animals, must have been deposited from the water. As they had often been raised and disturbed in their horizontal disposition, external forces had evidently been at work, and among these, Steno thought, volcanism played an important part.

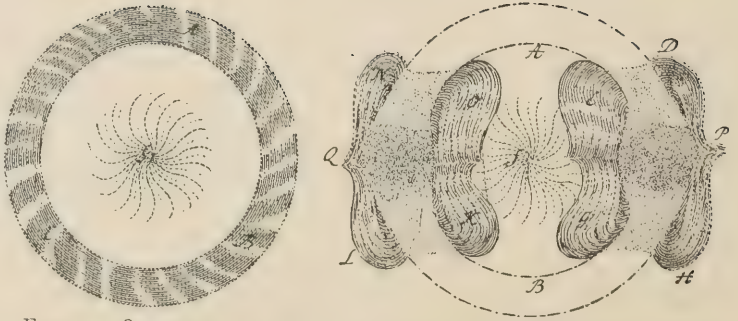
It was generally accepted then, that water filled the interior of the Earth, communicating by veins with the water of the ocean. Remarks to this effect have already been mentioned in our comments on Descartes. Eminent advocates of this erroneous opinion were Woodward (1665–1722) and Urban Hjärne (1712); the latter considered the water to be dense, turbid and boiling hot.

The ideas of Descartes were welcomed with the greatest admiration by his contemporaries. They began to replace the Aristotelian philosophy of the universities. In Upsala they caused a lively controversy which perhaps gave an impulse to the development of natural science in Sweden. The clergy attempted to prevent the proclamation of these novel doctrines from the academical chairs; but they did not succeed in obtaining the consent of the government to this oppression.

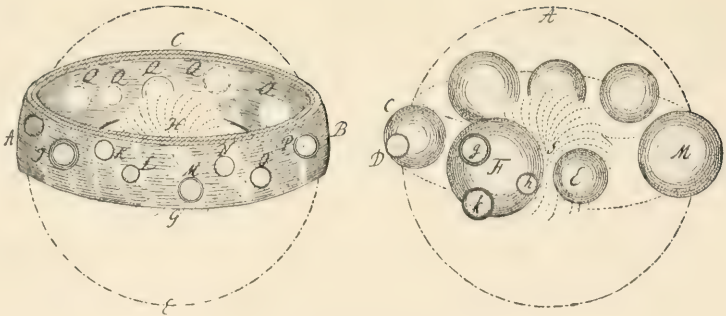
Among the young men, upon whom the teaching of Descartes made a very lively impression,

there was one, Swedenborg, who modified the Cartesian cosmogony to a certain extent. According to Swedenborg, all things consist of vortices, the atoms as well as the solar system. Everything is built up according to one universal scheme. The simplest material particle is supposed to arise from the vortex motion of the immaterial point. This is a very weak argument; for a point without dimension may oscillate ever so rapidly, it cannot thereby occupy any space. It would appear that Swedenborg attempted to explain the origin of the world out of nothing on these lines. Although he suggests in some passages that the mathematical point has been in existence from eternity, he is by no means consistent in this respect; for he says in another place, that the point itself had been created.

The cosmogony of Swedenborg differs from that of Descartes in so far, as he assumes that the planets did not migrate into the vortices of the solar system, but they were, on the contrary, ejected from the Sun. Swedenborg imagined that the sun-spots increased, and finally obscured the whole luminous surface of the sun. The imprisoned fire then sought to escape and to expand, and the surrounding shell became strained and broke at last. The dark shell was then gathered into a belt about the solar equator. The vortex afterwards continued to rotate, until this solid ring itself broke up into small fragments, which



FIGS. 17, 18, 19, 20. Formation of a planetary system out of the solar vortex, according to Swedenborg. Fig. 17 shows the solar vortex S as all surrounded by a solid spherical shell A, B, C. This shell is broken and falls (Fig. 18) from the poles of the vortex towards its equator, about which it forms a belt (Fig. 19). The particles I, K, L, M, etc., consist of solar matter. Finally, the belt breaks, and out of its parts are shaped the spherical planets C, F, M, etc, and the moons D, g, h, k (Fig. 20). The planets are carried by the vortex around S, until they reach positions in which they are in equilibrium with their surroundings.



FIGS. 19, 20.

aggregated to spherical masses; in this way the different planets and moons (as well as the sun-spots) had been formed. When a sun was bursting its shell, it suddenly became visible; this is Swedenborg's explanation of the sudden flashing-up of new suns.

The planets and moons, Swedenborg suggests, are then carried away by the vortex, till they reach a position, in which they are in equilibrium with the vortex-æther about them. At this distance they will move in almost circular paths. They behave just like a light body, which rises in the air and which does not come to rest, until it is in an atmosphere of the same density as its own. The specifically heaviest planets would, therefore, be the innermost, while Descartes placed those planets which had the greatest mass furthest outside.

Both these views are only approximately correct, as will be seen from the following table, which has been compiled according to the calculations of the American scientist See.

	Radius.	Mass.	Mean Distance.	Density.
Sun	109·100	332750·0	0·00	0·256
Mercury	0·341	0·0224	0·39	0·564
Venus	0·955	0·8150	0·72	0·936
Earth	1·000	1·0000	1·00	1·000
Moon	0·273	1·0123	1·00	0·604
Mars	0·536	0·1080	1·52	0·729
Jupiter	11·130	317·000	5·20	0·230
Saturn	9·350	95·1	9·55	0·116
Uranus	3·350	14·6	19·22	0·390
Neptune	3·430	17·2	30·12	0·430

In this table the radius of the Earth, its mass, its mean distance from the Sun, and its density are taken as units.

There prevails in Swedenborg's works a general want of clearness, which is incomprehensible to modern scientists. One gains the impression that he cannot properly have considered, what he was writing down. At the conclusion of his "Principia" he gives a mathematical expression to his vortex motion; in that part we certainly should expect to find complete lucidity. The vortex is, of course, limited on the outside with regard to other whirls. Swedenborg now asserts that, if the distances of two planets from the external vortex limit should be in the ratio of 1 to 4, their velocities should vary as 1 : 2. That would imply that the force, which urges the planet towards the centre, should vary in the same proportion as the distance of the planet from the vortex border and inversely as its distance from the Sun. But this force is exactly Newton's gravitation, which is inversely proportional to the square of the distance of the planet from the Sun, and this is not at all in agreement with Swedenborg's explanation. Yet Swedenborg was well acquainted with Newton's work, and he expresses on several occasions his deep admiration for him by saying "that he had never been sufficiently praised." In order now to compromise between his own view and Newton's view, which was generally accepted, Swedenborg proposes that the latter view would be correct when the vortex motion increased towards the edge of the vortex. This, however, does

not at all concur with Newton's law of the motions of the planets, and is in fact almost inconceivable.

The suggestion is thrown out by Swedenborg, that the Milky Way played, in the visible stellar Universe, the same part as the rotational axis of the Sun within the planetary system. According to this notion the suns with their planetary systems would lie grouped about the great axis of the Universe, which would run through the Milky Way, and the Milky Way would appear like a semicircular arc on the sky, whilst it seems to be ring-shaped. In the same manner we might, according to Swedenborg, imagine still larger systems, of which the Galaxy system (our Milky Way) only formed a small part. Similar ideas were later re-advanced by Wright (in 1750), who probably did not know Swedenborg's arguments and who assumed that the Milky Way corresponded to the ecliptic of the solar system. Further by Kant (1755), who hardly added anything to the explanation of Wright, and by Lambert, who believed that the suns would group themselves into star clusters, and the star clusters to Milky Ways, etc. (1761).

We may ask, why Swedenborg, with all his admiration for Newton, would not introduce his epoch-making discovery into his own system. The answer is that Swedenborg was quite governed by the idea that everything in the world, the large as well as the small, must have been made according to one plan. It appeared impossible to

him to imagine any action at a distance between celestial bodies, since such action appears otherwise strange to us. That objection was, indeed, raised against Newton's grand discovery from various sides, and Newton himself was not altogether insensible to it. For this reason Swedenborg based his cosmogony on Descartes' vortices. He does not appear to have felt the physical impossibilities of his assumptions, and particularly not to have understood their absolute incompatibility with Newton's laws. That is a very serious defect in Swedenborg's system, which yet contained some sound ideas that were later to receive further development from others.

This applies especially to the assumption, that the planets owed their existence to the Sun, and that they had originally belonged to the solar system, an idea which is generally ascribed to Kant. The idea that the Milky Way represents an immense stellar system is of no little value either, although Swedenborg did little towards developing it. A striking feature of his line of argument is the demand that the axes of the solar systems, which lie near our Sun, should all approximately point in the same direction. This direction should be parallel to that of the nearest portion of the Milky Way, which is not the case, however. The latest researches of Bohlin, of Stockholm, prove, that it is to a certain extent probable, that the planes of the orbits of the double stars nearest

to us and the mean plane of the largest (that is to say, to us nearest) nebulæ are approximately parallel to the ecliptic. According to Wright and Lambert, a similar regularity might be expected with regard to the suns of the Milky Way.

Pythagoras, it is said, used to tell his pupils, that other planets were inhabited like the Earth. The general acceptance of the system of Copernicus implied, as a matter of consequence, that our Earth could not be the centre of the Universe, and other worlds were thought to be peopled like our own. Giordano Bruno preached with enthusiasm this doctrine, which the theologians of those days considered so dangerous that it had to be expiated at the stake. It was no doubt especially this doctrine which rendered the Church so wroth against Galilei and other adherents of the Copernican system. When that view conquered in spite of everything, people fell into the other extreme. All the cosmic bodies were considered to be peopled, without any inquiry whether the physical conditions admitted of the existence of living and human beings. Phantasms about the people of the Moon were very popular in those days, and they are still familiar features of popular stories. The great astronomer William Herschel inclined to the belief, that even the Sun might be inhabited, and that the sun-spots formed portions of the solid solar continent which at times shone through the luminous solar clouds.

The visions of Swedenborg represent the strangest fantasies of this kind. Swedenborg was an extraordinarily conscientious man, and there can be no doubt, that he really believed what he maintained. He relates that he had spent days and weeks, sometimes even months, in the company of spirits and angels from other worlds. "From them I received communications concerning the other worlds in which they dwell, their customs and manners and religions, and other interesting things, and everything that has come to my knowledge in this way, I may describe as something that I have myself seen and heard." "It is a reasonable conclusion that large masses such as the planets which partly exceed in size our Earth, cannot merely have been created for the purpose of circulating about the Sun in order to send their spare light to one solitary Earth; they must have been shaped for a different object." This line of reasoning, which Swedenborg ascribes to the spirits from strange worlds, is probably very common and has, no doubt, a main share in the great interest which astronomy excites above all other science. "The planets," Swedenborg's spirits inform us, "revolve about their axes and have day and night. Several of them are accompanied by moons that travel about them just as our Moon does about our Earth. The planet Saturn, which is furthest removed from the Sun, has in addition a huge ring which supplies its

planet with ample, though reflected light. How can anybody, who is acquainted with these facts and who is capable of reasoning, assert that the celestial bodies should be unpeopled?" "It is well known to spirits and angels, that the Moon and also the satellites which circulate about Jupiter and Saturn are inhabited." Those inhabitants are described as intelligent beings similar to man. "Even those, who have not conversed with spirits, cannot have any doubt that these celestial bodies are inhabited. For they are Earths, and where there is an Earth, there are also men; for man was the ultimate purpose of every Earth." Swedenborg obtained in this manner knowledge and information not only about the planets of our solar system, but also concerning the inhabited worlds and other Suns, down to the very borders of the visible Universe. His spirit was transplanted into those regions, whilst his body remained on Earth. Thus he learnt that our Sun is larger than the other suns of the heavens. For, from one of these planets, he saw all the stars of Heaven and one among them which was greater than the others, and a voice from Heaven explained to him, that that was our Sun. Another time he was on a planet which was pointed out to him as the smallest in the Universe, scarcely 3750 km. in circumference. Frequently he speaks also of the animals and plants on the other planets.

This picture may be considered as characteristic for the ideas of the Universe held by the educated in Swedenborg's time. It deviates considerably from our present view, as Proctor, who has drawn attention to these speculations, remarks. Our Sun is certainly not the greatest of all suns. Nor is that little planet that Swedenborg describes by any means the smallest of the Universe. The largest of the 600 minor planets, which have been discovered since 1800, Ceres, has a circumference of about 3000 km. Vesta and Pallas have not even half so large a circumference, and the very smallest cannot be more than 30 km. in circumference, if we may judge by the intensity of their lights.

It is exceedingly characteristic that none of the spirits, whom Swedenborg met in twenty-nine years, had any knowledge of the numerous minor planets. Their statement that Saturn was the outermost planet, is equally incorrect, since Uranus and Neptune * were afterwards discovered

* The discovery of Neptune is one of the triumphs of mathematical astronomy. The irregularities in the movements of Uranus suggested the existence of an unknown planet further out. John Couch Adams, of Cambridge, submitted in 1845, and again in 1846, the results of his calculations to Challis. A search for the planet was not made, however. U. J. J. Leverrier read two papers on the same subject at Paris in 1846. Not being on good terms with his chief, the Paris astronomer, however, he asked Galle, the great astronomer of Berlin, to look out for a planet of a certain mass and velocity in a certain part of the sky, where Galle at once discovered it in September, 1846.—H. B.

(in 1781 and 1846). Uranus had in fact already been observed by Flamsteed in 1690, that is to say, about the time of Swedenborg's birth, 1688. It is visible to the naked eye, and no doubt people without number had seen it, although before the days of Herschel nobody thought, it might be a planet.

Very striking is also the assertion that the inhabitants of Mercury should enjoy a very comfortable climate, in spite of the violent radiation from the Sun, which must be 6·6 times stronger than upon the Earth. The explanation was supposed to be the very small density of the planet's atmosphere. That a rarefied atmosphere would have a cooling effect, Swedenborg concluded from the surprising cold everywhere observed on high mountains, even in the tropics. This Swedenborg himself told the people of Mercury, who are described as little intelligent. According to our actual views, living beings can hardly exist upon Mercury.

From all this we clearly perceive that the spirits and angels, with whom Swedenborg imagined to converse in his visions, could not communicate to him any more than what he himself knew, or what he regarded as probable. Measured by our present knowledge the information, which he acquired from those revelations, laboured under exactly the same defects as the common scientific beliefs of those days. I have reproduced Sweden-

borg's account of his spirit communications only with the object of showing how a learned man of his type imagined the cosmic system, and not at all for the purpose of giving an idea of this remarkable man's profound knowledge which, according to his own conviction, he had acquired by supernatural means.

It is very characteristic for that age that Kant also, no doubt induced by Swedenborg's example, dwelt in his "Theorie des Himmels" at length on the properties of the reasonable beings inhabiting the other planets. He confines himself, however, to the solar system. With a deficiency of critical power which is unfortunately not very rare, he asserts: "This relation has a degree of credibility, which is not far removed from established certainty."

Just as the different planets have higher specific gravities, the nearer they are to the Sun, he says (and this presumption is wrong), thus the materials, out of which the planetary inhabitants and also the plants are composed, must be of lighter and finer qualities, the further removed those planets are from the Sun.

At the same time the elasticity of the tissues of their bodies and their suitability must increase with the distance. The intellectual qualities, especially the capacity for thinking, the rapid grasp, the definiteness and intensity of their conceptions, the power of combination, rapidity of

action, in short, the general perfection of their talents should similarly increase with the distance of their abodes from the Sun.

This opinion appeared all the more necessary to him, because the day of Jupiter only lasts ten hours, a time which hardly suffices to an inhabitant of the Earth with his " coarser " nature for getting enough sleep. Both Kant and Swedenborg suggested that the numerous moons which move about the outer planets were in existence in order to rejoice the inhabitants of those planets ; sin was not known to them, virtue probably ruled supreme on those planets.

Thus writes the greatest philosopher of that time, who could not quite free himself from the naive metaphysical and teleological sentiments of his contemporaries. The teleological interpretation which demands a purpose for everything postulated, as Swedenborg expressed it, that man was the object for which the Earth existed. This teleological doctrine exercised at that time somewhat the same influence as the doctrine of evolution does at present.

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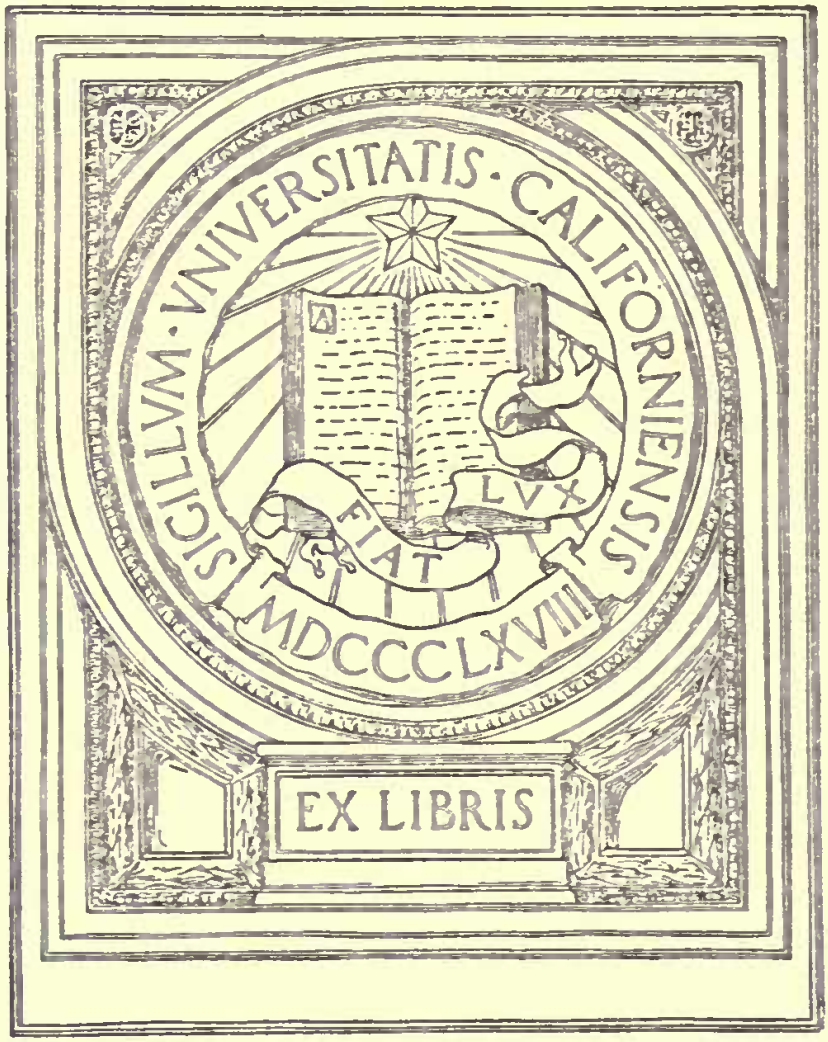

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THE LIFE OF THE UNIVERSE

BY

SVANTE ARRHENIUS

VOL. II

HARPER & BROTHERS
LONDON & NEW YORK

THE LIFE OF THE UNIVERSE

AS CONCEIVED BY MAN FROM THE EARLIEST AGES TO THE PRESENT TIME

BY

SVANTE ARRHENIUS

DIRECTOR OF THE PHYSICO-CHEMICAL NOBEL INSTITUTE, STOCKHOLM

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TRANSLATED BY

DR. H. BORNS, LONDON

ILLUSTRATED

IN TWO VOLUMES

VOL. II

LONDON AND NEW YORK

HARPER & BROTHERS

45 ALBEMARLE STREET, W.

1914

First Published May 1909
Reprinted February 1914

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THE LIFE OF THE UNIVERSE

VI

FROM NEWTON TO LAPLACE MECHANICS AND COSMOGONY OF THE SOLAR SYSTEM

KEPLER'S discovery of the laws of the planetary movements had rendered it possible to predict the positions of the planets for a certain time. The main link in the chain of evolution was yet missing, however, and it was reserved to Newton to add it. He proved that the three laws of Kepler * could be deduced from one single law, viz. from the now universally accepted law of

* The three laws of Kepler are: I. The planets move in ellipses about the Sun, which is situated at one of the foci of the ellipses [each ellipse has two foci, and the Sun is at the one common to all the ellipses]. II. For each planet the radii vectores [lines drawn from the Sun to the planet] sweep over equal areas in equal times [which implies that the Earth moves faster in winter, when nearer the Sun, than in summer]. III. The squares of the periods of two planets are to one another as the cubes of their mean distances from the Sun. I and II were published in 1609, III in 1619.—H. B.

gravitation : the force acting between two masses is proportional to their mass and inversely proportional to the square of their distance. The intensity of the force of gravitation on the surface of the Earth was at that time known from the measurements of Galilei and Huygens. Since now the same force, in this instance, the attraction of the Earth acts, according to Newton, upon the Moon and keeps it within its orbit, the intensity of gravitation should have admitted of a comparative determination from the known distance of the Moon and the curvature of its orbit. Newton made that calculation in the year 1666, but he did not arrive at any satisfactory result.

It is not at all improbable, as Faye remarks, that Newton was induced by this failure to doubt the universal character of gravitation. It is certain that he did not resume his calculation before the year 1682, when it led to the desired result, being based upon more recent estimates of the size of the Earth. We may presume that the time was ripe for this discovery, as the saying goes. For four countrymen of Newton had already come very near making it. In any case it was welcomed with enthusiasm by almost all the contemporaries of Newton. Yet it remained very difficult to conceive, how the bodies could act upon one another at a distance, and how the planets could move in empty space. Their movements were so extremely regular that one could not

possibly suppose them to pass through any gaseous matter, be it ever so attenuated. Moreover, observations conducted with the barometer proved that the density of the air decreased rapidly with the height above the surface of the Earth. The Cartesian vortex theory had hence to be abandoned. All the heavenly bodies, including the comets, which had given Descartes so much trouble because their orbits deviate so greatly from circles, moved in paths which rigorously obeyed Newton's law.

The striking regularity and uniformity which prevails in the planetary system, was a mystery to Newton. In addition to the six then known planets, their ten satellites all move in the same direction, all nearly in the same plane, the ecliptic, and all in almost circular orbits. As Newton did not believe in any vortex movement, which would carry the celestial bodies along with it, he could not understand this peculiar regularity, and all the less, because the comets whose orbits seemed likewise to be dependent upon the attraction of the Sun, frequently did not at all move in the same direction as the planets. Without any justification, Newton drew the conclusion that the regularity of the planetary movements could not have any mechanical cause. He argues somewhat as follows: On the contrary, the marvellous arrangement, by virtue of which the planets move in almost circular paths and

are kept far apart from one another, therefore, and the suns are so far distant from one another that their planets cannot interfere with one another, must have been caused by an intelligent and omnipotent Being. According to Newton the planets had received the impulse to their motion by the creation. This assertion, which really is the opposite of an explanation, was most determinedly contested by Leibniz; a positive solution of the problem was, however, not arrived at.

The first who seems to have aspired to such an explanation was Buffon, the ingenious author of the "Histoire Naturelle" (1745). Buffon knew the writings of Descartes and Swedenborg, and as he rightly considered the manner in which Swedenborg imagined the separation of the planets from the Sun was unsatisfactory from a physical standpoint, he looked for another explanation. From the outset he emphasised the extraordinary improbability, that the inclination of the ecliptic to the plane of the planetary orbits would, by itself and merely owing to chance, never exceed $7\frac{1}{2}^\circ$ or $\frac{1}{24}$th of the largest possible inclination of 180°.

That point had already been accentuated by Bernoulli. The probability, that this inclination is mere chance, amounts for every single planet only to $\frac{1}{24}$th. For the five then known planets taken altogether the probability assumed the

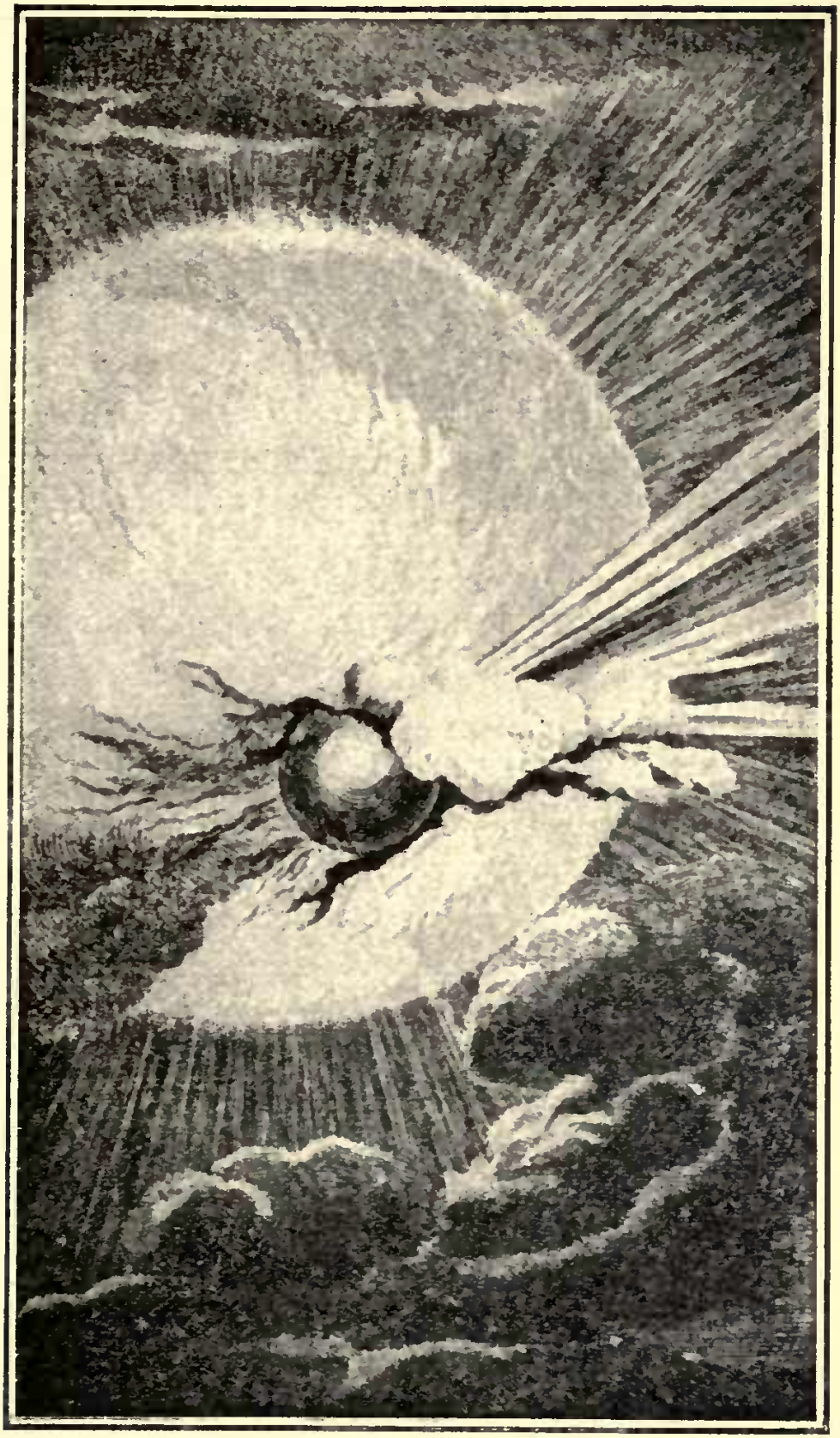

FIG. 21. Collision between the Sun and a Comet. Copper engraving in Buffon's "Histoire Naturelle."

value of 24^{-5}, or one eight-millionth. They had to consider in addition that the satellites, so far as then known, namely, the five moons about Saturn, four about Jupiter, the one of the Earth, and the ring of Saturn, were all moving in planes which deviated little from the ecliptic. A mechanical cause had to be found in explanation of these facts.

In order to explain the movements of the planets Buffon supposed that the planets had all arisen from collisions between the Sun and comets. About $\frac{1}{6\,5\,0}$th of the Sun's mass was assumed to have been knocked off and shifted, and out of that mass the planets and their moons were supposed to have been formed (Fig. 21). That such a tangential impact might occur seemed to be proved by the observation that the comet of the year 1680, whose orbit Newton had been calculating, had passed the Sun's luminous surface at a distance of only one-third of the solar radius; it seemed thus indeed possible that the next time, when the comet was expected to return, in the year 2255, it would fall into the Sun.

The objection may be raised that the fragments of the Sun would fall back upon it. Buffon's reply was that the comet would have displaced the Sun laterally, and that the original path of the torrents of matter which had been thrown out would to a certain extent have been altered by fragments ejected at a later stage. This suggestion was later approved of by Laplace, who

critically examined Buffon's explanation. The idea of Buffon is indeed ingenious. If we imagine a round disc of wood, into which a sharp tool is penetrating so that shavings are knocked off, as

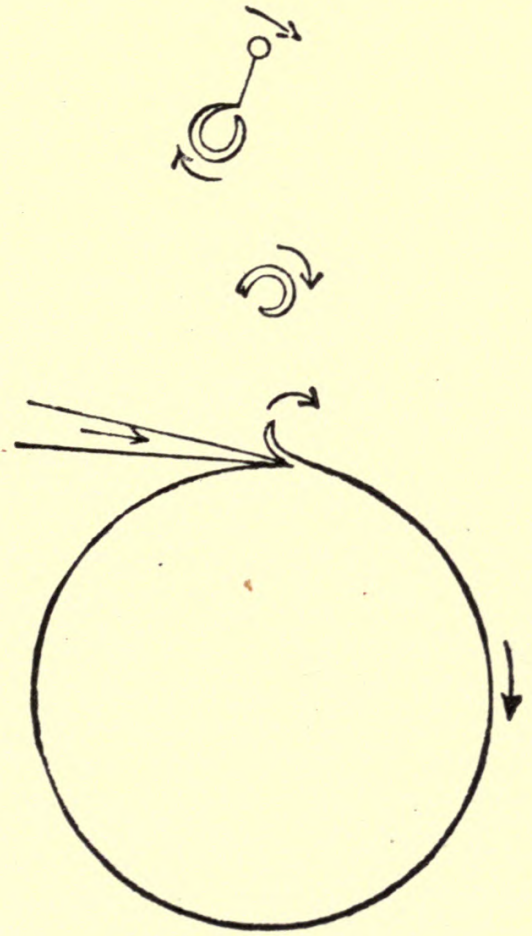

FIG. 22.

indicated in Fig. 22, the disc will assume a rotation in the direction of the arrow. The shavings which are split off will rotate in the same direction and they will further, owing to friction against the tool, be moving towards the right, that is to say

in the same sense and parallel to the direction of the movement of the equator of the disc. Smaller shavings, fragments of larger pieces, would commence to whirl about the larger pieces in the same sense, because they would be held back in the first instance by some finer fibres. In the same manner the fragments of the Sun, which had been produced when the comet penetrated obliquely to the surface of the Sun, would all rotate in the same direction and would, after the impact, travel in the same direction as the particles near the solar equator. Buffon regarded the Sun as a solid incandescent body, surrounded by an atmosphere and otherwise resembling the Earth. The little fibres, by the aid of which the small shavings were retained by the larger, would be replaced by the force of gravitation.

So far everything was right and good. Buffon went further. He argued in this way. Those fragments which possessed the smallest density would attain the greatest velocity and would therefore be hurled furthest away from the Sun, before their orbits would begin to curve. As he knew, that Saturn had a smaller density than Jupiter, and that the density of Jupiter in its turn was smaller than that of the Earth, he arrived at the conclusion that the planets would be the more dense the nearer they were to the Sun, a conclusion which had been drawn, as pointed out above, by Swedenborg and which reoccurs in Kant, but

which does not at all accord with our present knowledge. Further, the fragments which, at the moment of their separation from the Sun, possessed the largest equatorial velocity, would most easily have split off smaller fragments of their own, i.e. satellites. This assumption appeared justified in the light of the knowledge of those days, but is no longer so. People knew at that time only, that the equatorial velocity of Jupiter was greater than that of the Earth, and that of the latter greater than that of Mars. They knew, as mentioned, four moons of Jupiter and one moon of the Earth, but they did not know any moon of Mars. Saturn having five moons would hence possess the greatest equatorial velocity. Since then, however, we have arrived at the following sequence in equatorial velocities: Jupiter, Saturn, Earth, Mars, and at the following number of moons 8, 10, 1, 2. The above argument can, therefore, no longer be accepted.

The enormous evolution of heat caused by the collision would probably render the planets liquid, Buffon thought, but they would rapidly cool again owing to their small size, as the sun would cool and be extinguished some day. The different planets would remain incandescent for longer or shorter periods, according to their sizes. From experiments on the rapidity of cooling, which Buffon conducted with incandescent balls of iron of different diameters, he thought himself justified

in concluding that the Earth had required some 75,000 years to cool down to its actual temperature. To the Moon he assigned 16,000 years, to Jupiter 200,000 and to Saturn 131,000. The Sun would require ten times as long a time again as Jupiter.

In separating from the Sun the planets would have passed through the atmosphere of the Sun, and they would absorb from it air and water vapour, from which seas would later on be condensed. Long before that the interior of the Earth would have ceased to be incandescent, since no air could penetrate into it to feed the internal fire (this contradicts Descartes and Leibniz). Buffon believed that only two per cent of the terrestrial heat was being supplied by radiation from the Sun; the rest he considered the Earth's own heat. He further stipulated the same density for the Earth throughout its mass, because otherwise its axis of rotation could not have maintained a symmetrical position. But the shape of the Earth is exactly that which a liquid sphere of the rotational velocity of the Earth would assume. Nor is the Earth hollow; because gravitation would otherwise be greater on high mountains than it is.

The mean density of the fragments is almost the same as that of the Sun. For Jupiter, which makes up the chief mass of the planetary system, constituting about 75% of it, has nearly the same

density as the Sun, and Saturn which ranks next to it in size has a slightly smaller density. The inner planets, however, possess a greater density than the Sun. In these factors Buffon finds a confirmation of his views. As regards the latter two points, it should be remarked, that the rotational axis of the Earth would even then pass through its centre and through the poles, if the density at a point of its interior should only vary with its distance from the centre. Hence there would be nothing against the assumption that the Earth is denser in the interior than in its exterior strata, and we believe now that the ratio of the two densities is about 2 : 1. Further, the cooling of the Earth need not proceed at so rapid a rate as in the case of a ball of iron, which is a very good conductor of heat. The Earth may still be incandescent in its interior, although no combustion process is being carried on there. And finally we believe at present, that the Sun and probably also the outer planets comprising Jupiter, as well as the interiors of the inner planets, are gaseous and not, as Buffon surmised, solid. Under these circumstances his deductions practically lose their force; but they are incomparably superior to the view to which Kant later gave expression.

Buffon was a real scientist, who reasoned as we do at present. He was made the object of Laplace's criticisms, which were not unjustified,

and on this account his name is rarely mentioned now, whilst Kant and Laplace are always brought to the front. Yet it appears to me that Buffon's exposition well deserves a place next to that of Laplace, especially since it is fifty years older than the latter and Laplace by far surpasses the philosopher of Königsberg.

Buffon passes a rather bitter and yet apposite censure on the prolix and obscure cosmogonics of his time in the following words :

" I might have written as thick a book as Burnet or Wiston, if I had wished to expand my opinions in their manner, and I might have given weight to my deductions by clothing them in mathematical garments, as the latter has done. But I believe that hypotheses, however probable they be, should not be treated by such apparatus which savours just a little of charlatanism."

Laplace has rightly raised an objection to Buffon's system which no doubt has brought Buffon's theses into discredit. Buffon himself says : If a projectile be discharged from some point on the Earth, it will, if it describe a closed path, return to its starting-point and therefore remain only for a short time separated from the Earth, at the most for one revolution. In the same way the little split-off fragments of the Sun would turn back to the Sun. That they do not do so, is due to several additional circumstances. On this point the great authority in the domain of celestial

mechanics states: "The impacts, which the different particles that have successively separated will impart to one another, and their mutual attraction may alter their sense of movement, and their perihelia, that is to say, the points of their orbits nearest to the Sun, may recede further from the Sun." So far Buffon is right, therefore. But Laplace continues: "Nevertheless their orbits must be strongly eccentric, or it appears at least extraordinarily improbable that they should all be almost circular." Buffon had well understood that the orbits of the planets were approximately circular, but he had been unable to give an explanation of this regularity. His system had to be considerably modified therefore to make it conform to reality. It is, on the other side, very difficult to understand Laplace's remark, that Buffon would not have been able to explain the extremely eccentric orbits of the comets. For Buffon did not believe at all (as Kant later did) that the comets belonged to the solar system. He agreed with Laplace in assuming that they were immigrants from outer space. Under these circumstances their orbits could not but be strongly eccentric, as Laplace demonstrated. Buffon has not discussed this question at all. That may be a defect or an omission, but it cannot be characterised as a mistake.

We pass now to the work of Kant, twelve years later than Buffon's and inspired by him, and we

shall see that it cannot bear a comparison with Buffon's work.

Kant was a young man of thirty-one years and had not yet entered upon his brilliant philosophical career, when he published, in 1755, his book "Naturgeschichte und Theorie des Himmels," in which he deals with the just mentioned problems under application of Newton's laws. His cosmic space was empty, and the planets could not be carried through it by any vortices in the sense of Descartes. But provided the planets had once been set in motion, no further impelling force was needed for them in empty space. Why could we not assume, then, that the vortex which had started these planets on their trajectories had once existed and disappeared afterwards? That was Kant's happy line of reasoning; it somewhat recalls that of Anaximandros (compare p. 68).

"I therefore presume," Kant says, "that in the beginning all the matter which is now in the Sun, the planets and in the comets, must have been spread through the space in which these bodies now circulate." The attraction of the particles was directed towards the centre of this mass of dust, there where the Sun stands now. The material particles at once began to fall towards the centre of the mass. Kant imagines these particles solid or liquid; for he remarks, that the specifically heaviest particles would have the greatest probability of falling down upon the

Sun. It would sometimes happen that particles knocked against one another and were laterally deflected. Thus movements in closed paths—Kant speaks of circular orbits—would arise about the centre. The bodies, which moved in these paths, would again and again collide with one another, until these repeated collisions would have produced such a grouping, that they all moved in circular paths and in the same direction about their common centre. Some of the bodies, which were falling towards the centre, would likewise assume the same movement and would cause the Sun to rotate about its axis in the same direction.

Since now the distribution of matter about the centre was originally uniform, why should the final movement be from right to left, and not just as well from left to right? Aristoteles thought that the latter sense of movement, which he presumed for the celestial bodies turning about the Earth, was superior, more worthy of the gods. Kant holds that one of the two directions would prevail. That would be correct only if the material particles had from the very first possessed a vortex movement in some definite direction about a given point, as Descartes had supposed. But Kant does not make this hypothesis, and hence his exposition does not permit of the formation of a planetary system endowed with a definite predominating sense of rotation. It is strange that the great philosopher

Herbert Spencer should, a hundred years later, have fallen into the same mistake.

Kant further believed that in the matter once in vortex motion the heaviest particles would have the best chance of penetrating right through to the centre, before they had time to assume the final circular movement. For this reason the planets nearest to the Sun would possess the greatest density, as Swedenborg and Buffon had already asserted. But this is not so. Kant also maintains, that the central body would be specifically lighter than those nearest to it. But the Moon is less dense than the Earth ; Kant, we must add, was of the opposite opinion.

In the rings of meteoric dust which moved about the Sun there should be some portions of greater densities, and the other matter should gradually become concentrated about those parts. In that way planets and comets were said to have been formed. If the distribution of the particles in the rings were perfectly symmetrical, the planets would attain perfectly circular orbits, all situated in the same plane. Kant suggests that the deviations of the planetary orbits form circles and their inclinations to the ecliptic could be explained by a pre-existing want of symmetry. It is inexplicable, however, how such a want of symmetry could be pre-existing, since he had presumed a uniform distribution of matter about the Sun as centre during the course of its formation.

In another place he suggests that the smaller the intensity of gravitation, that is to say, the greater the distance of the planet from the Sun, the greater would also be the eccentricity of the planetary orbit. This is correct, as Kant states, for Saturn, Jupiter, Earth and Venus; but he does not mention Mercury and Mars, which show the greatest eccentricity after the minor planets, and which therefore would not fit into his system at all. Kant regards with Descartes the comets as outside and beyond Saturn; that would explain their great eccentricity.

The incorrectness of this view had already been proved by Newton and Halley. According to Kant the comets would also be specifically lighter than Saturn, which is probably wrong in so far as the comet's nucleus is concerned.

We see, therefore, that Kant's cosmogony is based upon a number of hypothetical statements which are not in accord with the actual relations. It would be of little interest further to illustrate this fact. It is more important to mention that, as Faye demonstrated, a planet which had been formed in Kant's manner by the contraction of a ring would have received a rotational movement opposite to that of the Sun and of all the planets which were known in Kant's days. If we imagine a ring, such as is represented in Fig. 23, the particles of dust further removed would according to the laws of planetary movements travel with

smaller velocity than those nearer to the Sun. If then such masses of dust aggregate to a ball, that ball would revolve from right to left more rapidly on its interior side turned towards the Sun than on its exterior side. In other words the direction of the rotation would be from left to right, that is to say, opposite to that of the Sun.

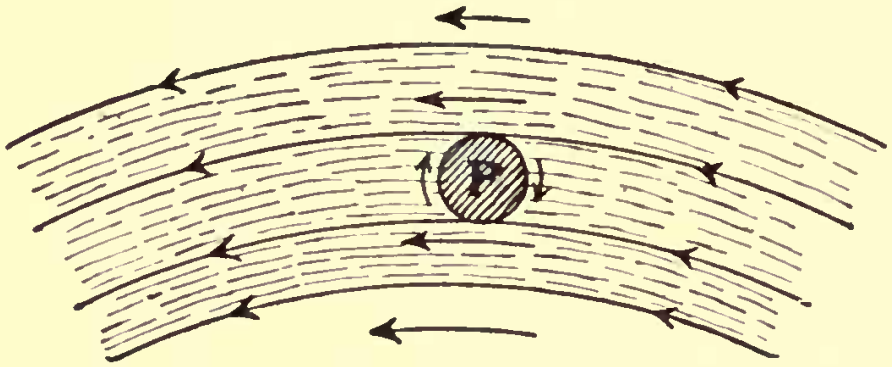

FIG. 23. Diagrammatic representation of a planet P which is in the course of formation from a circular stream of meteors moving about a centre situated below P.

The four central arrows indicate the velocities of the different portions of the swarm of meteors; this velocity decreases from below upwards. Since the rotational velocity is greater below P than above P, the latter will prevail in a collision between meteorites from the different belts, and P will therefore revolve in the opposite sense to the meteorites, that is, from left to right instead of from right to left.

It is peculiar that Kant offers a mechanical explanation for the formation of the rings of Saturn which fairly agrees with that given by Laplace for the formation of our planetary system. He starts from the assumption, that the whole mass of Saturn must originally have had a very large extension and must have

rotated about its axis. When it began to contract, some particles soon attained too high velocities to fall back upon the surface. They remained outside and formed ring-shaped collections of satellites. He also believes that the moons of Saturn may have arisen in a similar way. That he does not presume a similar original rotation for the evolution of the solar system, demonstrates how little he had really worked out this line of reasoning. In the Zodiacal Light he sees a faint ring formation about the Sun. There is another weak point in his reasoning. Kant imagines that those particles furthest inside the ring would originally have been on the equator of the planet and would from that position have risen to their actual height without change of velocity, an idea which is in direct contradiction to the laws of gravitation. He then calculates the velocity of Saturn at the equator from the period of the ring and he arrives at a period of revolution of 6 hours 23 minutes and 53 seconds. He is very proud of this result, "perhaps," he thinks, "the only prediction of its kind in the whole domain of natural philosophy." The period of Saturn, however, is 10 hours and 30 minutes. In this connection Kant also attempts to give an explanation of the deluge, a subject which greatly occupied the attention of the learned men of his day. The water under the firmament, which is mentioned in the first book of Moses, Kant thinks, was probably a ring-

shaped mass of water-haze about the Earth, somewhat similar to the ring of Saturn. This terrestrial ring was supposed to have served for the illumination of the Earth and, when man showed himself unworthy of this privilege, to have been used for punishing him. The ring suddenly fell upon the Earth and flooded it. Similar attempts of scientific interpretations of Biblical and classical tales reoccur over and over again in the scientific publications of that age.

Kant took up an idea advanced by Wright in the year 1750, according to which the mean plane of the Milky Way would correspond to the ecliptic of our planetary system. Just as the planets which move about the Sun do not travel far away from the plane of the ecliptic, so the stars would move in paths which little deviate from the mean plane of the Milky Way. These stars, to which our Sun also belongs, would themselves move about a central body whose position was unknown, but might possibly be ascertained by means of observations. According to Nyrén, Wright has put all the important features of this thesis quite as clearly as Kant.

Finally Kant has dwelt upon the extinction of the Sun. According to the then common view the Sun was a burning celestial body, and the end was to come from want of air and from accumulation of the ashes.

While burning the Sun had lost its most volatile

and finest particles, which formed the cloud of dust which he assumed to be the seat of the Zodiacal Light. Kant hints very obscurely that "the law concerning the extinction of the Sun includes a germ for the reunion of the dispersed particles, even if the latter should have intermingled with the Chaos." According to this passage and to some others, to which we shall revert again, Kant seems to assume that matter passed through a cycle of evolution, being now condensed to suns and then again scattered into chaotic confusion (compare the views of Demokritos, page 72).

Kant's cosmogony belongs to that class of theories according to which the planetary system originated from cosmic dust or a collection of small meteorites. This idea has been taken up later by Nordenskiöld and Lockyer and has been mathematically worked out by George Darwin. The latter has shown that a collection of such small bodies would in many respects behave like a mass of gas.

Laplace on the contrary, when attempting to give a mechanical explanation of the evolution of the solar system at the end of his "Système du Monde," starts from the assumption of a glowing mass of gas which from the very first was in vortex motion from right to left (as viewed from the north) about an axis passing through its centre of gravity. The difference between the two theories is essential, but has often been over-

looked. That may possibly be due to a statement made by Zöllner with regard to the nebular hypothesis, in which he intends to demonstrate that "this hypothesis was not founded by Laplace, but by Kant, Germany's philosopher."

The exposition of Laplace may be summed up as follows: "In its primitive assumed condition the Sun resembled those nebulæ which (compare Herschel's discoveries, page 149) are shown by the telescope to be composed of a more or less brilliant nucleus, surrounded by a nebulosity which is condensing upon the nucleus transforming it into a star. The solar mass cannot have extended out indefinitely. Its limits were the points, where the centrifugal force due to its motion of rotation was balanced by the gravitational attraction." The nebula contracted on cooling. From Kepler's second law each particle would in the unit of time (a second) describe an arc whose length would be inversely proportional to the distance from the Sun. The centrifugal force would consequently increase inversely as *the third* power of the distance from the centre, while the inwardly directed gravitation would increase inversely as the second power of the same term. When therefore the contraction of the glowing mass of gases continues, a gaseous disc is split off, as soon as the two forces become equal, and travels about the Sun like a planet (Fig. 24). Laplace hence assumes that the solar nebula would divide into rings of

FIG. 24. Diagram of ring formation from a nebula, according to Laplace. While the nebula is contracting, rings are formed about its centre, the Sun. Some of the rings have burst; in some condensations of nebulous matter are seen which are transformed into planets. From "Weltall und Menschheit."

glowing gases, each of which would rotate as a whole and cool down to a solid or liquid ring.

This, however, is physically impossible. During the cooling small dust particles would segregate and float in the gaseous medium. These particles would gradually grow to larger aggregates, on which gases would be condensed. Rings of dust would result, such as Kant imagined about Saturn, and these would after aggregation to planets turn in a direction opposite to the observed. Stockwell and Newcomb have, moreover, shown that such a coalescence to a single big mass could not take place. There would result, in its place, a collection of small meteorites such as circulate in the Saturn rings. According to Kirkwood the transformation of the Neptune belt into a planet would have required not less than 120 million years.

Further, all the planetary orbits would be circular and lie in the same plane. Laplace certainly says: "It may be conceived that the endless variety in the temperature and density of the various parts of this great mass produced eccentricity of their orbits and deviation of their motions from the plane of its equator." But he does not himself appear strongly convinced of this opinion, since he remarks later on, that comets (which in his opinion are strangers to the planetary system) came near the Sun and, colliding with planets in the course of formation, caused them to

deviate. Other comets would have entered the system when the condensation of the gaseous matter was nearly completed; they were so much retarded in their movement that they were incorporated into the solar system, keeping, however, an oval, long-drawn-out trajectory.

The most serious objection to the thesis of Laplace is probably the retrograde movement of the moons of Uranus and Neptune. The most remote moons of Saturn and Jupiter are likewise retrograde, while the other, inner satellites of these two planets turn in the normal sense.

We see that Laplace, while avoiding certain difficulties of Buffon's thesis (the small deviation of the planetary orbits from circles), is confronted by others not less serious. But Laplace gives us an excellent idea of the origin of the rings of Saturn.

The great contemporary of Laplace, Frederick William Herschel (born at Hanover in 1737, died at Slough near Windsor in 1822), studied the nebulæ with his telescope. They seemed to show stages of evolution (1811). Some nebulæ shed a diffused, greenish phosphorescent light; that appeared to be the primitive stage. Spectrum analysis has confirmed this view; the luminous masses consist of gases, chiefly hydrogen and helium, and an otherwise unknown substance, nebulium. In other nebulæ Herschel observed a faint central condensation nucleus. In others again he distinctly dis-

cerned stars; and there were others finally, in which the nebulous matter had almost vanished, being replaced by clusters of stars.

These simple, though most extensive observations have stood the test of subsequent examination much better than the highly admired thesis of Laplace. It should in justice be acknowledged, however, that Laplace apparently did not wish to give prominence to his thesis. For he published it as a note at the end of his classical work: "Exposition du Système du Monde."

This is the great work in which he inquires into the stability of our solar system. His conclusion is: "Whatever be the masses of the planets, it is only owing to the circumstance that they all move in the same direction and in almost circular orbits, at small inclinations to one another, that the secular variations in their orbits are periodical and within narrow limits, and that the system therefore oscillates about a mean condition, from which it never deviates by more than an insignificant amount." Laplace also demonstrated that the length of our day has not changed by as much as $\frac{1}{100}$th of a second since the year 729 B.C.

This conclusion, as to which he had the support of Lagrange, more firmly established the Newtonian doctrine of the wonderful stability of our solar system. It seemed to guarantee to the planetary system an eternal existence—strange enough, when

we remember, that the system was supposed to have had a beginning.

In this respect Kant's view is, no doubt, more consistent, or at least more in accordance with modern ideas.

VII

MORE RECENT ASTRONOMICAL DISCOVERIES

THE STELLAR UNIVERSE

WHILST Laplace confined the deductions, which we have just been discussing, to our planetary system, and while Swedenborg, Wright and Kant only expressed general opinions concerning the other cosmic bodies, of which opinions the most remarkable is perhaps that of Wright, that the stars of the Milky Way, as well as our own Sun, are always moving, Herschel made the whole immense stellar Universe his field of research. Halley (1656-1742) had already succeeded in observing that some stars had changed their position in the course of centuries and even in the time interval between Tycho Brahe and the end of the seventeenth century. Soon afterwards Bradley (1692-1762) mapped out his stellar catalogue with a hitherto unattained degree of exactitude. Herschel, who had this catalogue at his disposal in his inquiry into the change in position of the stars, observed that those changes were indeed quite considerable. He also noticed that

the stars seemed to be approaching one another in a certain portion of the sky, whilst they seemed to recede from one another in the opposite portion, and he explained this phenomenon by the change in the visual angle under which the objects appear. When we approach an object, the angle becomes larger, and when we recede from it, it becomes smaller. The objects are in this case the lines joining the stars. Starting from this base Herschel was able to determine the point, towards which the Sun and the constituents of its system are travelling.

This motion of the stars, first observed by Halley and then studied by Herschel, is known as the proper movement of the stars. It is generally determined by measuring the displacement of the stars on their background, the sky which is strewn with a multitude of stars at extraordinarily great distances. In most of those latter stars no movement whatever can be traced.

Great discoveries are generally received with doubt. No less a man than Bessel maintained that Herschel's discovery was doubtful. Argelander, on the other side, who deserves the greatest credit for his extraordinarily careful measurements of the stars and their positions and light intensities, supported Herschel, and his opinion has been confirmed by the later astronomers, among whom Kapteyn should particularly be singled out. The following pages are partly taken from Kapteyn.

Fig. 25 illustrates the movements of stars in a portion of the sky which is situated between the triangle, Andromeda, the Ram, and the Fishes. The small black dots indicate the present position of the stars; the straight lines starting from the dots indicate the paths along which these stars are expected to travel during the next three thousand five hundred years. We see at a glance that the constellations will look very different at the expiration of that period. The stars do not by any means move in parallel orbits, nor with equal velocities. Yet we distinctly recognise a predominating direction of movement, obliquely downward to the left. If we trace all the movements from one origin, as is done in Fig. 26, we clearly recognise this predominating direction. It is marked in the diagram by an arrow with a double shaft (Fig. 26).

When we plot such resultants of the directions of movement on the celestial globe we come to Fig. 27. The different arrows all radiate from one point of the heavens, which is designated the apex, and which is obviously that point towards which the Sun seems to be moving; for the stars appear to be receding from it in all directions. Of course, this holds only for a mean or average movement of the stars. Every single star will in its proper movement differ more or less from its mean. Hence it is evident that the stars must relatively become displaced, and that it is not the Sun alone

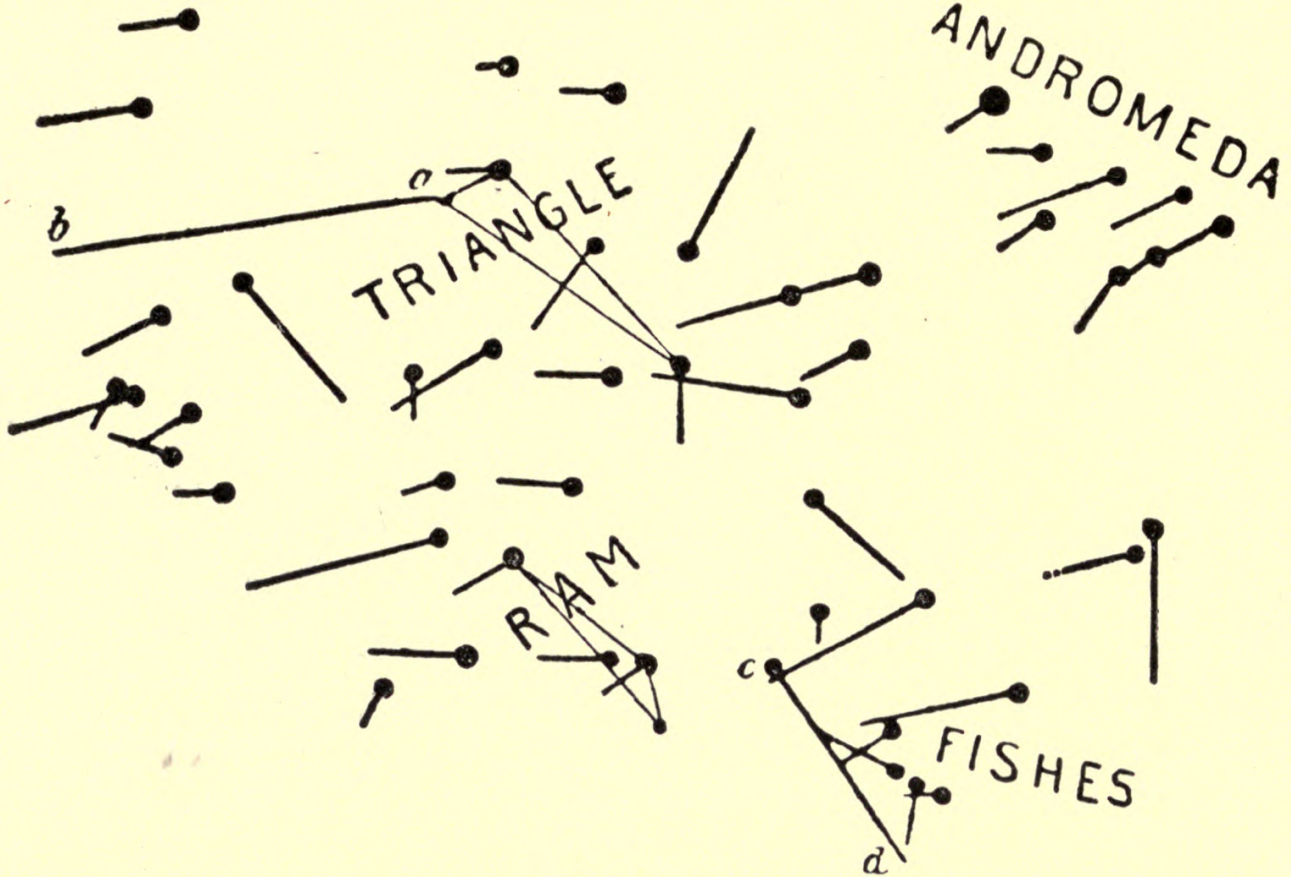

FIG. 25.

among all the crowds of star systems which is progressing. This last figure (27), which is due to Kapteyn, affords an extraordinarily instructive picture. For it proves incontestably that Herschel was right in his assumption. The Sun moves towards the point A on the sky situated in the constellation of Hercules, near its border on the side of the constellation of the Lyre. The Sun recedes from the constellation of the Great Dog, which is on the opposite side of the sky.

Schönfeld and Kapteyn have examined the assertion of Wright, that the stars of the Milky Way move in the same direction like the planets of the solar system. No certain indication of such a regularity has been demonstrated. But Kapteyn deduced another regularity. The proper movement of the stars seemed to him to suggest the existence of two distinct star streams. One of these is directed towards the star Xi in the constellation of Orion, the other in exactly the opposite direction. The further inquiry into these regularities should furnish us with most interesting clues.

These phenomena acquired a still higher interest, when we succeeded in determining the distances of some fixed stars from the Sun. We rely on their apparent movements in the sky in the course of a year. According to the views of Aristarchos and of Copernicus the Earth is moving in space. It must, therefore, at one time of the year be nearer

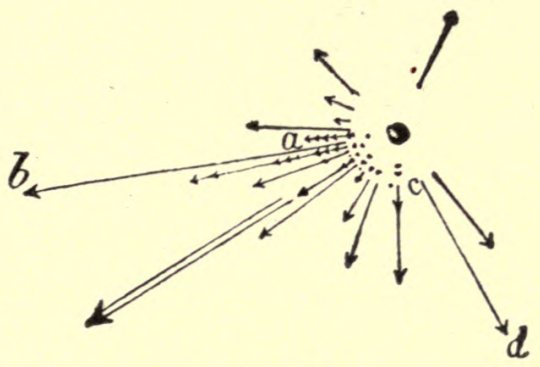

FIG. 26.

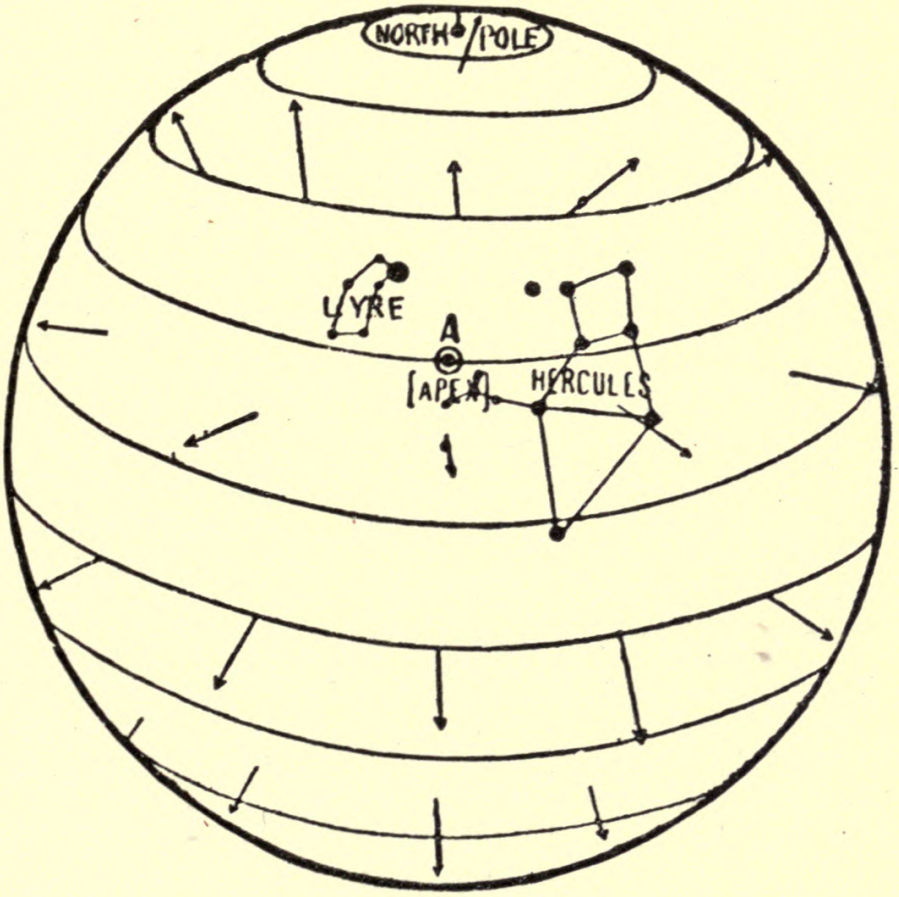

FIG. 27.

a certain star than in any other time of the year. We might then expect to notice certain changes of periodical nature and hope to find that the same constellation would alternately increase and decrease in size or brightness in the course of the year.

All attempts to verify such variations failed, however, and people were satisfied, as Aristarchos had been, that with the enormous distances of the stars the change in the visual angle, if any, could not be observable. Copernicus shared this opinion. Tycho Brahe considered variations so altogether out of question, that he saw in that fact one more reason to assume the Earth as fixed in space and as the centre of the Universe. The astronomers, however, never tired in their efforts to investigate this point further, and Arago and Bessel succeeded at last in 1809 and 1838 in establishing a very small annual to-and-fro movement (the stellar parallax) in the star 61 of the Swan. From this movement the distance of the star was derived. It proved so great that light would need ten years to travel from this star to the Sun; the distance amounts to 10 light years, as we say. One light year indicates $9{\cdot}5 \cdot 10^{12}$ or about ten billion kilometres, or 63,000 times the distance of the Earth from the Sun.

The distances of other stars have been determined with our ever-improving instruments. The star Alpha Centauri seems to be nearest to our Sun,

though the distance between the two yet amounts to 4·3 light years. Eight stars, among them Sirius, are distant 10 light years and less. The mean distance between stars in our portion of the Universe is a little more than 10 light years. We know of 28 star neighbours at distances of less than 20 light years, and of 57 stars within less than 30 light years. Aristarchos and Copernicus were right, and with this demonstration the last doubt as to the movement of the Earth in its own orbit was disposed of. When we know the proper movement, that is to say, the angular velocity and also the distance of a star, we can calculate their real velocity. This method, however, only yields us that component of the velocity which is at right angles to the line of sight. The following examples may be quoted: The velocity of Vega is 10 km., of Alpha Centauri 23, of Capella 35, of 61 in the Swan 60, and of Arcturus about 400 km. per second.

If we further know the velocity of the star in the line of sight, we can calculate its total movement. Spectrum analysis, which has altogether revolutionised stellar astronomy since its introduction in 1859, and the Doppler principle allow us to make even this determination. These velocities amount for the five just mentioned stars to −19, −20, +20, −62, −5 km. per second. A plus indicates that the star is moving away from the Sun, a minus that it is approaching the Sun.

The figures show that the stars have relatively great velocities. For the velocity of the Earth in its orbit is about 30 km. per second.

The point on the sky towards which the Sun is moving can still more easily be derived from the motion of the stars in the direction of the line of sight than from their proper movements. Campbell found in such a calculation that—assuming that the reference stars are on average stationary, that is to say, that as many of them move away from the Sun as towards it, and with the same velocity—the Sun would travel with a velocity of 20 km. per second towards a point which coincides very nearly with the spot calculated from the proper motions of the stars. We need no longer doubt, therefore, that the observed phenomena have been correctly interpreted. It would be of the greatest interest to ascertain whether the Sun is always approaching the same point in the sky and thus moving in a rectilinear path, or whether this path is slightly curved. From the magnitude of the curvature we should be able to determine which forces are influencing the movement of the Sun through space. The observations have, however, been carried on for far too short a period as yet to enable us to answer this question.

It is certain, however, that the stars are not all moving about one great common central body, like the planets about the Sun, in the sense that

Wright and Kant believed. Their motions in fact appear quite irregular. It is not improbable, therefore, that in its adventurous wanderings, the Sun might at some time or other encounter another star or a nebula. The Sun may have to travel for a hundred thousand billion years before it collides with another star of similar size and light intensity. But this period of undisturbed wandering may be greatly shortened, because there is probably a far greater number of extinct suns, than of luminous suns floating about in space. It would not be strange if the Sun were to drift into some nebula. They abound in the Universe, and many of them are seen to occupy immense areas, while even the most brilliant stars are mere points in our most powerful telescopes. It is often suggested that the Sun would be impeded in its course through such a nebula, and that the friction would raise its temperature to incandescence. It would then become a so-called new star, like the one which flashed up in Perseus in the year 1901. The following consideration will show that this latter conclusion cannot be correct. According to Laplace the mass of the solar system once formed a nebula which had spread out to a disc and which extended to the limits of the orbit of Neptune. If we assume the thickness of this disc to be on average not greater than ten times the actual solar diameter, the density of this nebula would yet approximately be 420 million

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times smaller than that of the Sun. If the Sun were to enter such a nebula with a relative velocity of 28·3 km.* per second, it would in the course of a year, traverse a mass of gases which could not be greater than two millionths of its own weight. The velocity would correspondingly be diminished. That would cause an increase of the mean temperature of the Sun by about 0·2°, presuming the specific heat of the Sun to be equal to that of water. But that coefficient is probably greater; for in general the specific heat of a body increases considerably with rising temperature. Even if this rise in temperature were chiefly confined to the external layers of the Sun and of the gases of the nebula with which it collided, the rise in temperature could yet be only very slow, and no sudden flashing-up could result, as in the case of the formation of new stars. Moreover an increase in the radiation of the solar heat by ten per cent would suffice to prevent any further increase of temperature. Such a small change in the brightness of the star would scarcely attract our attention. The nebula in its exterior portions would moreover be very much more attenuated than the above mentioned average figure.

* This number is the probable resultant of the relative velocities of the Sun and a nebula, each of which is moving with a velocity of 20 km. with regard to its surroundings. According to Campbell's determinations the velocities of nebulæ are of the same order of magnitude as that of the Sun.

A flashing-up might ensue only in case the Sun should collide with another star or should drift into the central concentrated portions of a nebula. The luminosity might then become several hundred or thousand times as large as before and afterwards, and the phenomenon would be suggestive of the formation of a new star.

Nebulæ may, on the other hand, be able to accelerate the occurrence of collisions between suns. A great deal of matter is collected in the nebulæ, having drifted into them from all sides and all portions of the heavens: Meteorites, comets, and above all cosmic dust. These wanderers through space possess so small a mass that they would be stopped by a nebula; nebulous matter would condense upon them, and they would gradually coalesce into larger bodies. The consequence would be the formation of small stars. If now the Sun should in its travels approach such bodies and collide with them, vast torrents of gaseous matter would project from the Sun and would reduce the velocity of the Sun. Its further motion through the nebula would thus be impeded. In this sense suns may finally be caught, so to say, after having for long periods wandered through nebular masses which occupy immense spaces. There is much more probability of a collision between a sun which has once drifted into a nebula and another sun, which has already been

caught in it, than of a collision between two suns, both travelling through the almost void space.

For all these reasons we have to diminish considerably the period of free travel which we allowed to the Sun for its motion through celestial space. It may not be too much to go down to one-hundredth of the above stated figure, that is to say, to about a thousand billion years. It need not be pointed out that such estimates are quite uncertain, and that we merely intend to give an approximate idea of the length of the life periods of celestial bodies.

The probable consequences of a collision between two cosmic bodies of the size of our Sun have been described at some length in my book, "Worlds in the Making." Two enormous streams of gaseous matter would issue forth from the two suns in collision and, rushing out into infinite space, they would assume the appearance of a double spiral which characterises such nebulæ. The torrents of matter would consist essentially of the gases which are most difficult to condense, especially helium and hydrogen, further of small particles of substances which are more easily condensed. All these would be endowed, by the eruption, with so great a velocity that they might escape from the range of attraction of the central body. Having then lost their velocity, they would for long periods remain in an almost unchanged position without being deprived of

their spiral shape. Masses which were thrown out with less violence would return to the heart of the eruption and collide with others which were thrown up at a later period. The whole matter would finally form a gaseous nebula of vast extent, interspersed with solid and liquid particles, about the central body which (as Buffon had already suggested) the collision would cause to revolve at a high rate. Furthest inside we should find the central body in a state of violent incandescence; it would have increased its volume very considerably after the collision and would on the outside gradually pass into the gaseous matter which whirls around it.

Somewhat in this way Laplace imagined the nebula from which the solar system has arisen. If we modify the ideas of Laplace and adapt them to subsequent observations, we obtain a picture of how the evolution of a solar system may commence anew in a nebula. In this picture we find the views of Buffon and of Laplace amalgamated to a certain extent.

The bright star Arcturus which rushes on with a velocity of about 400 km. per second has the greatest known stellar velocity. Its distance from the Sun amounts to about 200 light years, and the light which it emits strongly resembles our Sun's light. It must therefore be of immense size. Indeed, it has been calculated that it may be 50,000 times as large as the Sun. We may picture to

ourselves the results of a collision between two such giant suns travelling with enormous velocity. The ejected masses of gas would spread out through an immense vortex, unlimited probably in all directions in the plane of revolution. We might imagine that the Milky Way owed its origin to a collision of this kind, if it were not difficult to account for the fact that we do not know any central body in it (compare the view of Ritter below). In such a gigantic nebula a large number of small stars would collect in the course of millions of years, and they would probably collide and produce new vortices. Almost all the new stars occur in the neighbourhood of the Milky Way in which the stars themselves are incomparably much denser and more frequent than in other parts of the heavens. Of new stars we see after their extinction merely gaseous nebulæ, and these gaseous nebulæ are found abounding to a remarkable degree near the Milky Way. When the nebular masses have had time to condense upon the dust and matter which have drifted into them, star clusters will arise which again are most frequent in this region of the sky. To judge by their spectra, the spiral nebulæ are star clusters which are so far distant from us that we cannot distinguish separate stars in them any longer. They occur particularly in those portions of the heavens where stars are relatively rare, at the poles of the Milky Way and thus at the greatest distance from

it. There, however, they abound. Wolf counted, for instance, on a single plate, on which he had photographed a portion of the constellation : the Hair of Berenike, no fewer than 1528 nebulæ, most of which probably belonged to the spiral class.

It is to spectrum analysis chiefly that we owe elucidation concerning the composition of the stars. Herschel classified the nebulæ according to the apparent state of their development, and in the same way stars have been classified. We begin with the hottest, those which give luminous spectral lines and which therefore are most closely related to the gaseous nebulæ from which they have probably arisen, and conclude with the darkest, probably about to become extinguished. After these luminous stars we have the dark cosmic bodies, first those devoid of any solid outer shell (Jupiter is a probable example), then those provided with a hard crust like the Earth (compare "Worlds in the Making," page 186).

Among the elements which are most prominent in the stars we find helium in the hottest stars ; hydrogen in those white stars which follow next on the scale of temperature ; calcium, magnesium, and iron, as well as other metals, in the yellow stars of medium temperature to which our Sun belongs ; and finally carbon compounds, including cyanogen, in the least hot stars of reddish colour. It is not quite correct to assert that we have not

found in the stars any other elements than those known on our Earth. Pickering, for instance, observed in several stars spectrum lines which he could not identify with any terrestrial element. These lines have, on account of certain regularities in their wave-lengths, been ascribed with a considerable degree of probability to hydrogen, although we have not succeeded in causing hydrogen to emit this kind of radiation. A certain number of so far unidentified lines has also been found in the Sun. Of the spectrum lines which have been known for relatively short periods only, those of helium are the most important. The so-called coronal line which is characteristic of the inner corona of the Sun is one of the many unknown lines. Yet on the whole the spectrum lines of the stars and the lines of the terrestrial elements agree well. Maxwell said in the year 1873: We discover stars in space, by the aid of their light and exclusively by this aid, which are so far apart that nothing material can ever have travelled from the one to the other, and yet that same light tells us, that every one of those stars has been built up out of the same atoms that we find on our Earth. It is interesting to record that the same great scientist predicted in the same year the force by means of which matter might be transported from star to star, the radiation pressure. Three years later Bartoli demonstrated that it was not only

heat and light rays, but all kinds of radiation, which exercised this pressure in their radiations. Yet the cosmical importance of this new universal force was not heeded until I showed in 1900, that it admitted of explaining in simple ways many thus far inexplicable phenomena.

By the action of the radiation pressure small globules (spherical drops) of matter condensed in the solar atmosphere are pushed away from the Sun and wander through space with velocities which may attain a few per cent of the velocity of light. In the neighbourhood of stars whose radiation exceeds that of the Sun this velocity of the smaller globules may be very much increased, though it can never quite equal that of light. Indeed the high velocity appears to be the common rule; for most of the stars shed a white light in contrast to the yellow light of our Sun, and they radiate therefore at a higher intensity. Owing to this ejection of small particles which has been going on for uncountable ages, the suns are constantly exchanging matter. As a consequence any differences in the constitutions which might have originally existed would long since have been compensated. In this process, as in general in Nature, the colder bodies, in our case the colder stars, will gain at the expense of the warmer, and the larger will increase at the expense of the smaller.

It is not improbable, as I indicated in "Worlds

in the Making" (page 108), that the strange messengers from other worlds, the so-called meteorites, are composed of such spherules which had been driven into space. The meteorites are distinguished, by an entirely peculiar structure and composition, from all the rocks and minerals known on our Earth, from the so-called plutonic, which have been formed by the congelation of the liquid interior of the Earth, as well as from the neptunic, which have been formed upon the bottom of the sea. Frequently these meteorites contain enclosures of vitreous nature which suggest their having been cooled at a very rapid rate. In other cases they contain large crystals which indicate that they must have been exposed to the same temperature for long periods. Adjoining parts of the same meteorite may show striking differences in composition and in structure. That suggests that their materials must be of very different origin. They do not contain any water, nor any hydrates (compounds with water), and this appears quite natural; for their particles have been produced in the neighbourhood of the Sun, where hydrogen and oxygen have not yet combined into water. But they contain hydrocarbons, which are frequent in the spectra of the faintly luminous stars and of sun-spots, and further chlorides, sulphides and phosphides which are unstable on the Earth and which can only have been produced in an atmosphere which was devoid of

water and of oxygen. On the other hand the minerals which are common in our plutonic rocks are missing: quartz, orthoclase, acid plagioclases, mica, amphibol, leucit, and nephelin, minerals which have been produced by the so-called differentiation of the magma issuing from the interior of the Earth.

To bring about that differentiation a long-continued diffusion in large molten masses would be required, which cannot take place in small drops. All these peculiarities, as well as the very frequent fine-grain structure, which is designated chondritic structure, are easily compatible with the origin of these meteorites from small spherules. That large crystals are occasionally met with might be due either to the presence of some solvent (carbon monoxide for iron or nickel), or to the fact that a portion of the respective meteorites was for a long time exposed to intense heat, as would be the case of comets when they are near the Sun. Schiaparelli's classical investigations in this domain have proved that comets, especially when near the Sun, are resolved into swarms of meteorites.

These little drops which are ejected and propelled by the Sun will collect chiefly in the widely spread gaseous masses of the extreme portions of the nebulæ which owe their luminescence to the electrically charged dust. This light is characteristic of the peculiar gas spectrum of nebulæ.

In the intense cold of the nebulæ the drops will condense part of these gases, in particular the hydrocarbons and carbon monoxide, upon their surface. When such masses collide with one another they will be cemented by these materials. In this way small drops or spherules will gradually grow into meteorites which will continue their migration through space.

In addition to these particles, which are ejected by the radiation pressure, the suns exchange by their collisions part of their gaseous matter which will spread through space. Matter may also travel from sun to sun, because gaseous molecules of the outer portions of nebulæ may, by virtue of the radiation absorbed from far distant suns, attain so great a velocity that they separate from the nebula and rush out into space (compare "Worlds in the Making," page 195). Maxwell's opinion, that nothing material can have wandered from one star over to another, can therefore no longer be accepted.

The last twenty years have enlarged our knowledge of the nature of thermal radiation to an extraordinary extent. Among the laws established those of Stefan and of Wien are the most important. Stefan's law says that a body which does neither reflect any radiation, nor transmit it, will emit an amount of heat which is proportional to the fourth power of its absolute temperature (reckoned from -273° C. as absolute zero). The

law of Wien teaches us, how the total radiation of a body is composed of many different kinds of radiations corresponding to the colours of the spectrum. The temperatures of the planets and moons provided with a solid crust can be deduced from the first law. This has first been done by Christiansen. The quantity of heat which the respective body receives from the Sun is known. As the body has a solid crust, it radiates almost as much heat into space as it receives from the Sun, and its temperature will therefore be approximately constant. The temperature can hence be calculated from the connection between radiation and temperature, such as results from the laws of radiation (compare "Worlds in the Making," page 46). In the case of planets and moons, which are not surrounded by an atmosphere, such as Mercury and our Moon, this calculation leads to correct values.

The presence of an atmosphere will change the relation to a certain extent, as Fourier pointed out already at the beginning of the nineteenth century. The reason is that the atmosphere transmits the incident solar rays to different degrees and generally to higher degrees than the heat rays emitted by the dark surfaces of the bodies. Water vapour and carbonic acid play an important part in these considerations, as I have discussed on other occasions. Most geologists agree, that the successive geological periods, of which fossil

organisms give evidence, were chiefly caused by fluctuations in the percentage of carbonic acid in the atmosphere, and this percentage again depends on the intensity of the volcanic activity of the period (compare "Worlds in the Making," page 52).

The knowledge of our planetary system has further been enriched in an important measure by our learning to determine the absolute mass of the Earth, from which its specific density could easily be calculated. Such measurements were first conducted by Cavendish in 1798. He compared the attraction which a large ball, 30 centimetres in diameter, exerted upon a small spherical pendulum, with the attraction which the Earth exerted upon the same ball. He deduced a specific gravity of the Earth of 5·45. Cavendish's experiments have since been repeated and modified by many scientists, and the final result is the figure 5·52 for the mean density of the Earth. Since now the outer strata of the Earth crust average a density of about 2·6 (that of the ordinary rocks), we have to assume that the interior of the Earth must be much heavier. Nevertheless we believe that the interior of the Earth, starting from a depth of about 50 km., must be liquid, since the temperature rises in bore holes by about 30 deg. cent. for every kilometre. The observations of the propagation of earthquake waves, as well as pendulum observations, confirm us in this assump-

tion (compare "Worlds in the Making," page 36). At still greater depths, of about 300 km., the whole nucleus of the earth would probably be gaseous. But the pressure at that depth must be so extraordinarily high, that it matters little for the density, whether the substances there are in the solid, liquid, or gaseous state. It is the temperature which is the really decisive factor. If therefore the planets nearest to the Sun have a much higher mean density than those further remote than the Sun itself, the reason would probably be that the former have a much lower mean temperature, and that the latter (by contrast to the others) probably are not enclosed in a solid crust. What we call surface in these celestial bodies, is merely that portion which we perceive through our telescopes and which consists of light clouds floating in the most extreme layers of the gaseous mass. The great mean density of the Earth seems to imply that the core must contain heavy metals. We have reason to assume in particular that iron is a very important constituent of the interior of the Earth, as well as of the metallic meteorites and of the Sun.

In the year 1675 the Dane O. Römer, assistant to the famous astronomer Cassini in Paris, made a discovery of the greatest astronomical importance. He found that it was possible to measure the velocity of light. He was observing the moons of Jupiter which Galilei had discovered. These

moons are obscured when they enter into the shadow of the planet, and these eclipses can be observed with the greatest accuracy. Since now the periods of cosmic bodies are invariable, the time elapsing between two successive eclipses should also be constant. Römer's observation did not confirm this assumption. If the Earth were as close to Jupiter as it can come in its orbit, and if both the planets were stationary, these eclipses should occur at exactly equal intervals, let us say, of one day and eighteen hours. If the Earth were immediately after the eclipse to rush over to the opposite point of its orbit, the next eclipse, which, of course, would follow again within one day and eighteen hours, should be apparently delayed by the time which the light requires to pass across the diameter of the Earth's orbit. That would be an average 997 seconds. Römer found a much higher figure, 1320 seconds. Now the earth of course does not describe one half of its orbit in so short a time as one day and eighteen hours; in fact during that half-orbit 105 eclipses are taking place, because the Earth is moving all the time, and we have to add eleven more eclipses on account of the movement of Jupiter. But the time interval remains the same. From his observations and the probable length of the axis of the Earth's orbit, Römer estimated the velocity of light at 313,000 km. per second. If, on the other hand, we could

determine the velocity of light upon the Earth, then we might calculate from this delayed occurrence of the eclipses the true diameter of the Earth's orbit. This has been done. The best-known determinations of the velocity of light have been made by Fizeau, Foucault, and Michelson. According to these determinations the velocity of light is 300,000 km. per second in empty space. The radius of the Earth's orbit should then be 149·5 million kilometers. Direct astronomical determinations have given almost the same figure.

Since the days of Laplace two great planets, Uranus (1781) and Neptune (1846), have been discovered, and further the many minor planets which are circulating between Mars and Jupiter (of which there are now about 600 known). The first one was detected by Piazzi on January 1, 1801, and called Ceres. They all move in the normal direction, anti-clockwise. Their orbits are inclined at different angles. The greatest inclination is 34·83°. The eccentricities of their orbits are also very different, the maximum being 0·383.

The double stars offer a particular interest. They have been studied with remarkable assiduity by W. Herschel, later by W. Struve, and recently by See. In several cases we have been able to determine the motion of these stars about their common centre of gravity; from that it became possible to calculate the eccentricity of their orbits. In quite recent time the study of stellar spectra has taught

us that a great many of the stars are moving to and fro. In their case as well it has been possible to determine the orbital eccentricities. These eccentricities are very different from those of the orbits of our planets, which are nearly circular. The eccentricities of stellar orbits range for the directly observed stars from 0·13 to 0·82, and their mean value is, according to See, 0·45. The spectroscopically studied double stars show smaller eccentricities. They range for 18 double stars, which are catalogued in Newcomb's "Treatise of Popular Astronomy," between 0 and 0·52, the mean value being 0·18.*

In the case of a few double stars we have succeeded in determining the masses of the two bodies. Taking the mass of our Sun as unit, we find: Alpha Centauri 1 and 1, Sirius 2·2 and 1, Procyon 3·8 and 0·8, the Star 70 in Ophiuchus 1·4 and 0·34, the Star 85 in Pegasus 2·1 and 1·2. We see from these figures that almost all these stars are larger than our Sun. The study of spectroscopic doubles has led to a similar result. In some instances the one of the two stars is too faintly luminous to be visible, and is hence called a dark companion. The variable star Algol which is occasionally obscured and partly covered by a dark companion offers a very peculiar example, in

* The more recent determinations by See fix the mean value of the eccentricities of the two classes of double stars at 0·50 and 0·22 respectively.

which the mass of the stars is relatively small. The diameter of Algol has been estimated at 2,130,000 km., that of its companion, at 1,700,000 km. Both are therefore considerably larger than the Sun, whose diameter is 1,391,000 km. Nevertheless the masses, as derived from their periods, do not appear to be more than 0·36 and 0·19 of the mass of the Sun. Their specific gravity is only 0·1 of that of the Sun. Another variable star, Z in Hercules, consists, according to the observations of Hartwig, of two giant suns which move about one another at a distance of 45 million km.; their diameters are 15 and 12 million km., their masses 174 and 94 times as large as the mass of the Sun, and their specific gravities 0·138 and 0·146. It looks strange that the smaller, dark body should have almost as small a density as the larger star; but a similar relation holds for the densities of our Sun and the large planets. The double star U in Pegasus has according to Myers a mean density of about 0·3 of that of the Sun. Roberts estimated the double star V in Puppis as having a mass 348 times as large as that of the Sun, but only one-fiftieth of its density. Myers also calculates for the well-known variable star Beta in the Lyre a 30 times larger mass, but a 1600 times smaller specific gravity than for the Sun. Although these calculations cannot be called reliable, they yet prove distinctly that our Sun is, as to size, a relatively small star,

but that it has already attained a very high degree of density, and should hence be in a relatively advanced stage of evolution. That it is only a faintly luminous star, we understand, when we inquire into the distance of the stars. At the distance of Arcturus or Beteigeuze the Sun would no longer be visible to the naked eye, and at a distance which corresponds to the average distance of the stars of the first magnitude, our Sun would appear to us like a star of the fifth magnitude, that is to say, it would rank with the just barely visible stars.

The relatively unimportant position of our Sun is no doubt partly to be explained upon the ground that it is the largest and most splendid of the stars which have been studied. Kapteyn has attempted to effect a kind of compromise by calculating how many stars of different brightness, taking the brightness of our Sun as unit 1, would be found in a sphere of a radius of 560 light years, whose centre is the Sun. The following is the result :

1 star	has a	brightness	of	more	than	10,000		
26 stars	have a	brightness		between		10,000	and	1000
1300	,,	,,	,,	,,		1000	,,	100
22,000	,,	,,	,,	,,		100	,,	10
140,000	,,	,,	,,	,,		10	,,	1
430,000	,,	,,	,,	,,		1	,,	0·1
650,000	,,	,,	,,	,,		0·1	,,	0·01.

We notice in this table that a strong increase in the number of stars is accompanied by a decrease

in the light intensity. We may therefore assume that the dark cosmic bodies will by far exceed the number of bright ones. They need not necessarily be of lesser mass for all that, although we must suppose that the brightest stars will also possess great volumes and therefore great masses; their densities might yet be very small owing to their high temperatures.

The circumstance that the orbits of double stars appear to be of remarkably high eccentricity, by contrast to those of the planets, has been quoted in support of the assertion that the grand regularity of our planetary system must constitute an exception. This is not a forcible proof at all. The nebulous revolving disc resulting from the collision between two stars constitutes in general only a small portion of the whole mass. The largest part remains in the central body. A large portion of the matter outside the central body is dispersed into space by virtue of the velocity of the ejected particles. Some of the most rapidly oscillating molecules also escape, whilst the rotating disc is constantly becoming enlarged owing to the absorption of radiation from space. If now a strange body drifts into this revolving disc from space, two cases may arise. When the mass of this body, e.g. comet, is relatively small, the disc may force it to take part in its rotational movement. A planet would be formed, and it would move in a nearly circular orbit and in the plane of the disc. But

when the immigrating body has a mass which is large by comparison with that of the disc, the latter might yet be able to diminish the velocity of the former to such an extent that it would not be able to escape again from the central body of the nebula. The matter in the disc could only slightly modify its orbit, and this orbit would consequently become very strongly eccentric and might take place at any inclination towards the plane of the disc. This latter case was precisely that of the actual comets in the solar system according to Laplace. As now in the former instance the mass of the newly formed planet is relatively small, it would rapidly lose the small amount of luminosity with which it was endowed, and it would not be directly visible. Owing to its small size its influence upon the movement of the bright central body would further be very small, and the oscillating movement impressed upon the latter much too unimportant to enable us to draw any conclusions with regard to the presence of a dark companion. These instances would probably be more frequent than those in which a big cosmic body is caught; if only for the reason that the small celestial bodies, e.g. the comets, are relatively so common. They abound like the fish in the sea, says Kepler. Most of the large bodies of the Universe would be able to force their way through the nebulous masses without suffering a noteworthy reduction of speed

which would impede their further wanderings through space. Normal cases of this type would rarely fall under our observation. Where a large celestial body enters as a component into a double star under formation, the already existent planets would probably assume very complicated orbits.

W. Wien's law of the displacement of the wave-length of maximum energy with changes of temperature has also been applied for the determination of stellar temperatures. Very rigorous care must be exercised in these attempts. For the star light that we see is not the total radiation of the star, but a light that has been weakened by absorption in its outer atmosphere (compare "Worlds in the Making," page 71).

The temperature of a star may further be deduced from the intensity of its spectrum lines. Certain lines of the absorption spectra of gases are intensified with rising temperature, others are correspondingly weakened. Hale and his collaborators on Mount Wilson in California have investigated the spectra of metals which they evaporated in two series of experiments in arcs of 110 volts, both of 2 amperes and of 30 amperes. The second arc was naturally warmer (still hotter is the electric spark passing between metallic point electrodes of the respective metals), and thus they could investigate the changes in the spectrum lines caused by a rise of temperature. Comparing two spectra they would thus be able to

say, which of them belonged to a higher temperature, and they could judge whether, for instance, the light of a star or of a sun-spot suggested a higher or lower temperature than that of the solar disc. Hale concluded that the gases which absorb the light of solar spots have a lower temperature than those which absorb the light of the solar disc. This is due, no doubt, to the great density of the gaseous masses situated above the sun-spots; but it does not prove that the radiating bottom of the spot has a lower temperature than the clouds of the photosphere which radiate the light of the solar disc. By such comparative studies it has been demonstrated in Hale's laboratory, that the spectrum of Arcturus and the spectrum of Beteigeuze deviate in the same manner from the solar spectrum as the light of the sun-spots does. We may hence conclude that the absorbing gases in these immense stars, and especially in Beteigeuze, have a lower temperature than those above the solar photosphere. But the radiating strata need not for all that be colder in those stars than in the Sun. It appears, on the contrary, probable, that the lower temperatures of the outer layers of gas are due to the greater density of the absorbing gaseous medium.

The tidal phenomena, which G. H. Darwin has studied in a classical research, have exercised a great influence upon the development of the planetary system. Darwin shows that in all

probability the Moon just after separating from the Earth kept pretty close to it, and that the whole system completed one revolution within a little less than four hours. The tides, which were extraordinarily intense under these circumstances, gradually increased this rotational period of the terrestrial system, and the lost energy of rotation was partly expended in lifting the Moon slowly away from the Earth to its present distance. A similar tidal effect was exercised by the Sun upon the planets in the first stage of their development when they still had very large diameters; for the intensity of this effect is proportional to the third power of the diameter.

By these means the rotational velocities of the Sun as well as of the planets were diminished, and their distances from the Sun were altered. Darwin explains the peculiar observation, that the period of one of the moons of Mars, Phobos, is shorter than Mars' own period, by assuming, in accordance with Laplace, that Mars must originally have had a shorter period than Phobos. The tides caused by the Sun lengthened the period of Mars, so that it is now, with 24 hours and 37 minutes, much longer than the period of Phobos, which occupies 7 hours and 39 minutes.

It is similar with the ring of Saturn. The masses of dust nearest to the planet have a rotation period of 5 or 6 hours, whilst the period of the planet itself is $10\frac{1}{4}$ hours. In view of the very great

distance of Saturn from the Sun it is generally conceded, however, that the explanation cannot be given on the lines which apply to Mars. But would it not be possible that the matter in the innermost ring of Saturn might have approached its planet and thereby increased its rotational velocity? Something of that kind might occur owing to friction between the matter in the ring and a small portion of the planetary atmosphere. Laplace made such a suggestion, and C. Wolf shares this opinion.

We have pointed out one of the objections to the hypothesis of Laplace which equally applies to that of Kant, that the directions of the rotation of the planets should be the opposite to that of the Sun. All the planetary movements should be retrograde. Pickering assumes that all planets actually did start with a retrograde movement,* but that they lost it by the tidal action of the Sun, the result being that they finally always turned the same side towards the Sun, that is to say, that they assumed a normal rotation, equal in period to that of their orbital movement. By virtue of the subsequent contraction their rotations were again accelerated. The two outermost planets, Neptune and Uranus, are so far away that the Sun did

* According to the views which have been set forth in this book the original direction of a planet's rotation was not subject to any regularity and depended upon the direction of motion in the original nucleus of condensation which came in from outside.

not exercise any sensible tidal influence upon them during the period of contraction. As their mass amounts only to about one-sixth of that of the next planet Saturn, they must have cooled much more rapidly than the latter. These planets could therefore deviate from the general rule. As regards Saturn, the first nine moons are normal, the ninth being Japetus, which is nearly 3·5 million km. from it. The tenth moon, Phœbe, discovered by Pickering, is 3·5 times further removed and is retrograde. Pickering thinks that it may have been formed at a time when Saturn itself was still retrograde. Considering its great eccentricity (0·22), we should more probably liken Phœbe to the comets of the planetary system; it may only have come within the range of Saturn's attraction when the nebulous matter of this region had become greatly attenuated. Similar conclusions may be drawn as regards the outermost known (eighth) satellite of Jupiter. All the inner planetary satellites behave regularly.

Most of the discoveries which we have discussed in this section concern cosmic bodies situated outside our solar system. It was only after the introduction of powerful telescopes and particularly with the aid of the spectroscope (since 1859) that we succeeded in gaining a deeper insight into the peculiarities of these far-remote structures. Yet four hundred years before the beginning of our era Demokritos had taught that the stars in

the Milky Way resembled our Sun, and at the dawn of the modern age Giordano Bruno had dreamt of planets which were wandering about fixed star-suns. They were possessed by the conviction which guides the scientist in all his researches, that the relatively unknown will in its essential features resemble that which is near to us and which we have been able to study more closely. Experience has proved that Demokritos and Bruno were in the right, and that this principle of natural science will on the whole lead us to correct conclusions. The stars will be like our Sun, some smaller, some larger, some colder, some hotter than our great star.

Herschel found that some of the nebulæ which he examined were different from the Sun as regards light and extension. Spectrum analysis has corroborated him. Those nebulæ consist of widely spread attenuated masses of gas of a kind that we do not meet in our solar system. But by examining them and comparing them with other similar structures, he discovered a series of intermediate types between nebulæ and suns, and he concluded that these various forms represent different stages in the evolution and transformation of the Universe.

It was on this base that Laplace placed his famous hypothesis of the origin of the solar system. The extraordinarily manifold wealth of subsequent observations has entirely supported Herschel

in all his essential points and has at the same time elucidated our ideas concerning the character of the cosmic bodies.

No doubt we are even now only in possession of the very first rudiments of a knowledge of the stellar world, and we must still content ourselves with believing, together with Demokritos, Bruno, Herschel, and Laplace, that the yet unexplored regions of space will in the main resemble those which we have succeeded in examining by the aid of more perfect instruments. It appears in the highest degree probable that the future, with its deeper insight, will not differ as to essential facts, while ideas may take new and bolder flights of which the present generation knows nothing. Our knowledge will continue to improve, and the opinions of the scientist of past generations will undergo a further logical development. The superficial observer often gains the impression, that one system of ideas implies the subversion of the others, and it is often our lot to hear from those, who are not students of natural science, that all our endeavours to gain clear conceptions are wholly in vain. Whoever follows the course of evolution with some care will find to his great satisfaction, that our knowledge is growing like a strong tree from unpretentious seed, and he will always recognise the further growth and development of the same tree, although every part and especially the external clothing of leaves may con-

tinuously be renewed. The tree and the leading ideas have survived. Those ideas have remained unchanged in spite of the changes which circumstances have undergone in the course of hundreds and thousands of years.

VIII

THE ENERGY CONCEPTION IN COSMOGONY

IN concluding his classical work on the stability of the solar system to his own satisfaction Laplace gave expression to the hope that the Sun would continue to emit its life-spending light to our planets for indefinite periods. The conditions within the solar system would remain fairly unchanged for ever. The great astronomer felt no more called upon to offer an explanation for the continuity of the intense solar radiation, than his perhaps still greater contemporary Herschel had done.

That, however this inquiry into the cause of solar heat and of the glow of the stars was well worth examination did not escape the attention of Anaxagoras, who thought that the stars became incandescent by friction with the æther. Leibniz and Kant expressed the opinion that the solar heat was sustained by combustion, and the same idea of finding a solution for the heat problem is implied in Buffon's remarkable calculations upon the time which the planets had

required for cooling down from incandescence. Laplace too assumed that the matter, from which the planets had originated, must first have been in a state of incandescence and have subsequently cooled.

But it was only when the mechanical theory of heat started on its victorious course through the different domains of science in the middle of the last century that a firm basis for such considerations was found. The mechanical theory of heat teaches that energy is as indestructible as matter. The amount of matter had tacitly been accepted as invariable by all, who had meditated on cosmic problems, although the demonstration was only given by Lavoisier at the end of the eighteenth century. The introduction of the conception of energy dates from the past century.

If the Sun sends out its life-giving rays into infinite space, it must in some way be able to make up for the loss of energy, or it must cool rapidly. The latter assumption is disputed by geologists, who maintain that the solar heat has been radiated upon the Earth at an approximately constant rate for nearly a milliard of years. Robert Julius Mayer first attempted to find a source for this energy in the inrush of the meteors ; Helmholtz improved this idea of Mayer's. Helmholtz thought that every particle of the Sun must slowly sink towards the centre and thereby engender heat. This solution of the problem was

generally regarded as the best and most satisfactory; but the recent investigations of geologists have more and more clearly established that this source could not be sufficient (compare Chapter III of "Worlds in the Making").

As the behaviour of substances, and especially the qualities of gases and their changes with varying temperature and pressure, became better understood, the dependency of the temperature of cosmic bodies upon changes in their volume, as well as upon the supply or loss of energy by absorbed or emitted radiation, was more thoroughly investigated. The most remarkable of these inquiries has been supplied by Ritter; we shall presently deal with it.

The utilisation of our knowledge concerning the influence of temperature upon the chemical reactions, that may possibly occur between the different constituents of a cosmic body, is now promising to come to our aid in these speculations regarding the purely physical changes in those bodies due to temperature and gravitation. Very probably these investigations will help us to a safe way out of the difficulty in which Helmholtz left us, when he confined his consideration to the relatively small amount of energy which is being liberated by purely physical processes, disregarding the far more powerful sources of energy in chemical reactions. This discussion will be carried further in the next chapter.

The remarkably comprehensive researches and deductions of A. Ritter just mentioned will exemplify how far we can proceed when we apply the laws of gravitation and of the indestructibility of energy to physical processes. Ritter starts from these two principles and presumes further the validity of the ordinary gas laws, whilst he assigns a secondary importance to heat conduction and to heat radiation. Similar inquiries had been published, eight years before, in 1870, by Lane. Later on Lord Kelvin, See, and especially Dr. Emden (1907) supplied valuable contributions towards the solution of this problem. The latter deals with the subject in a grand mathematical treatise which will be of great value for future workers in this field. In physical respects he does not go much beyond Ritter. The influence of radiation has recently been studied by Schwarzschild. We will in this place confine ourselves to the chief results of Ritter's exposition.

According to Ritter a mass of gas which obeys his laws will in general have an outer limit at which the temperature will be down to absolute zero. If we start from that border, the temperature will increase towards the interior and will at every spot be exactly that of a mass of gas that would have fallen from the limit down to this point. The matter will better be understood if we take the terrestrial atmosphere for exemplifica-

tion. Let the temperature on the Earth's surface be 16° C. (289 degrees upon the absolute scale), which actually seems to be the average temperature of our surface, then, according to Ritter, the height of the atmosphere would amount to 28·9 km. For, when one kilogramme of water falls through one kilometre, its temperature will be increased by $\frac{1000}{426} = 2{\cdot}35°$ C. Since now the specific heat of air is 0·235, the same quantity of heat, which would raise the temperature of one kilogramme of water by 0·235°, would be able to raise the temperature of one kilogramme of air by one degree. A kilogramme of air falling through one kilometre would hence become warmer by 10°. (In this calculation we follow Ritter, who takes the specific heat of air at constant pressure.) In order now that the temperature of the air should rise by 289° above absolute zero, it should fall through 28·9 km., and that would be the height of our atmosphere.

If our atmosphere consisted of hydrogen, whose specific heat is 3·42, the atmosphere would attain a height of 421 km. The atmosphere would also reach up to a very considerable height, if it consisted of saturated water vapour and small drops of water suspended in it. To raise the temperature of that mixture by one degree, we should have to heat, not the steam only, but to supply heat for the evaporation of the water. The result would be the same as if the specific heat of the

mixture were relatively high. Ritter calculates that the height of an atmosphere consisting of water vapour should be 350 km., starting from a surface temperature of 0°. Now we know, that the air really contains some water vapour and clouds in addition to the less condensable gases. For this reason we add 2 km. to the height of 28·9 km. at which we had just arrived.

The resulting value does not at all accord with the usually accepted figures, as Ritter has himself pointed out. Shooting stars, observations prove, frequently flash up at an altitude of more than 200 km. above the surface of the Earth. There must hence be sufficient air and oxygen at that altitude to cause friction and combustion. The arcs of the northern lights, which we explain as electric discharge phenomena, have their highest points at an altitude of about 400 km. Observations made in balloons within recent years show that at a height of a little more than 10 km. the temperature becomes nearly uniform; it does not continue to decrease, while it decreases by about 10 degrees per km. in the lower strata.*

Ritter finds the explanation of this deviation from his deduction in the fact, that the gases of the air are condensed to clouds at very great heights, just as water vapour is condensed in the

* This so-called isothermal layer is found near the equator at an altitude of more than 20 km., in central Europe at an altitude of 11 or 12 km., and in latitude 70° at 8 km. altitude.

lower atmospheric strata. The height of the atmosphere should then be considerably increased.*

From what we know at present this condensation of oxygen and nitrogen cannot take place when the temperature exceeds —200°; that would be met at a considerably higher altitude than that which balloons have hitherto reached and in which the temperature gradient vanished. Meteorologists differ as to the explanation of these phenomena. I myself am inclined to believe, that heat radiation and heat absorption by the carbon dioxide and the water vapour in the air, possibly also by the ozone, play an important part in these processes.

Ritter calculates further, what would be the temperature of the centre of the Earth, if we were able to drive a wide air-shaft right through the Earth. He does not forget to consider that gravitation would change with the depth of the shaft, becoming zero at the centre of the Earth. Allowing for this he deduces for the centre of the shaft a temperature of about 32,000°. The temperature of the Earth at the centre should, according to other calculations, be about 100,000°. From these estimates we can form an idea as to the temperature rise in the interior of gaseous cosmic

* Goldhammer has calculated that the atmospheric height would be 62 km. for nitrogen and a little more than 70 km. for oxygen.

bodies. In so far as the Earth at the depth of 400 km. is pretty certainly gaseous, Ritter's calculations may have a certain justification in this instance. The specific heat of the gases confined in the Earth will, however, no doubt be much greater than the value Ritter assumed for his gases. That would lower the calculated temperature of the centre of the Earth. If we take into consideration the possibility of chemical reactions, the estimate may have to be reduced by more than one half, perhaps to one or two tenths. The pressure at this depth may be estimated at something like three million atmospheres.

We can now return to our consideration of the Sun. Gravitation is in the outer strata of the Sun about 27·4 times greater than upon the Earth. The temperature would therefore increase by about 274° per km., if the solar atmosphere consisted of air. But that atmosphere contains chiefly the gas hydrogen dissociated into atoms, while on our Earth hydrogen occurs in the molecular state, each molecule consisting of two atoms. The specific heat of mon-atomic hydrogen, at the temperature which prevails there, may be estimated at about 10, that is to say, 42·5 times as high as that of the air at freezing point. In the highest gaseous strata of the Sun the temperature would therefore vary by about 6·5 degrees per km. Since now the temperature of the luminous solar clouds has been estimated at 7500 degrees,

the solar atmosphere above them should attain a height of some 1200 km. Yet the pressure in this atmosphere does not, according to Jewell's research on the position of the absorption lines, exceed five or six atmospheres. On the Earth the pressure would be about 27·4 times smaller, i.e. about 0·20 atmospheres. The mass of gas situated above the luminous solar clouds would then not be greater than the mass of air above 12 km. altitude, where only the highest cirrus clouds are floating.

The thickness of the so-called chromosphere of the Sun has been determined during solar eclipses. It is the depth of the layer of gas which shines in the peculiar pink colour characteristic of hydrogen ; this depth has been averaged at 8000 km., and that is more than six times as much as the value just mentioned. We hence come to the same conclusion as with respect to the Earth, viz. : that the atmosphere must be many times higher than it would be according to Ritter's deductions.

It would moreover be incorrect to assume that the temperature would sink down to 0° or still lower in the outer strata of the solar atmosphere. The radiation is far too strong there to permit of so intense a cooling effect. There are no doubt many condensed particles in these regions of the solar atmosphere ; we conclude this from the weakening of the Sun's light as we go outward from the solar limb, when the light has to pass through

the higher strata. These particles or drops are heated by solar radiation and they impart their own high temperature to the surrounding gas. It is the same thing as in our own atmosphere, where the many dust particles absorb the solar radiation, assuming a temperature of 50° or 60° which they then communicate to the surrounding gases. In both cases the decrease of temperature with increasing height would be slower than Ritter considered, and for that reason the atmosphere would again be many times higher than Ritter's estimate.

We come back to Ritter's research. He has calculated, how pressure, temperature and density should change with the depths in a gaseous, spherical nebula. I have reproduced these calculations as modified by Schuster in "Worlds in the Making," page 198. According to these calculations the temperature in the centre of the Sun, if it consisted of atomic hydrogen gas, would be 25 million degrees, the pressure 8·5000 million atmospheres, and the specific gravity 8·5 (water equal 1). The table which is given on the page quoted practically shows only that, if the Sun were to expand to a nebula of ten times its actual radius, the temperature at the centre of this nebula would be 2·5 million degrees. But the contraction to the present size of the Sun would increase the force of gravity in the ratio of 1 to 100, and the temperature gradient per km. would

rise in the same ratio. Since, however, the radius has been reduced to one-tenth of its original dimension, the temperature at the centre of the mass would be one hundred tenths of its old value, that is to say, ten times higher than in the nebula. That applies for every other point of the Sun, and the temperature increase consequent upon contraction would be inversely proportional to the solar radius. On the other hand, the gases of the Sun, owing to their strong compression, would certainly no longer obey the simple gas laws, and for that reason Ritter's temperature estimate must be diminished. Assuming the Sun to consist of iron in the gaseous state, Ritter would arrive at a temperature of 1375 million degrees. The exceedingly high temperature would give rise to energetically heat-absorbing chemical processes which would again produce a strong reduction of the temperature. We finally come to an average solar temperature of something like 10 million degrees.*

When a mass of gas, such as the nebula under consideration, contracts, its temperature increases as was pointed out, and this increase is obtained at the expenditure of a great quantity of the heat which, in Helmholtz's opinion, would be liberated by the contraction. If there were no chemical processes, we should have to allow 81 per cent of the above-mentioned figure for heating, and only

* Ekholm indeed finds the lower value of 5·4 million degrees.

19 per cent would remain for radiation. In this part Ritter reckons with bi-atomic hydrogen, H_2; in the case of mon-atomic hydrogen, H, we should have to allow 50 per cent for radiation. Under these circumstances the Sun could not maintain its actual radiation for more than 5 (respectively 12) million years. The solar radiation must already have diminished considerably during the past ages. Ritter was well aware that the geologists demand very much longer periods for the existence of life on the Earth. Like most physicists he was convinced that the source of solar heat assumed by Helmholtz was by far the most important, and he did not attach much weight to the conclusions of the geologists. Later investigations have, however, further strengthened the arguments of geologists in favour of a higher age of our Earth and of a more invariable radiation of the Sun. Both van't Hoff's researches on the temperature which must have prevailed during the formation of the immense salt deposits in the different geological periods, as well as the geographical distribution of coral reefs in those ages, prove that the temperature of the Earth's surface, and consequently the intensity of solar radiation, cannot much have changed since these remote ages.

We are therefore forced to search for a source of heat, which will be both greater and less variable than the one considered, which is based

on the contraction of the Sun. Such a source of heat we find, no doubt, in the chemical reactions which take place during the slow cooling of the Sun. Those reactions would take place in the opposite sense during the contraction of the solar nebula, and it would hence result that the contraction of the Sun must have been still more rapid than Ritter assumed. Supposing that the radiation remained constant, scarcely a million years would be required for the cooling of the nebula reckoning from the time of the collision. During the time that the Sun was still in a nebular stage, it must, however, have stored up enormous quantities of energy by the absorption of radiant heat from outside. This energy, later on, when its own mean temperature commenced to fall, was spent in replenishing the losses of heat. Thus the temperature, and hence the extension of the Sun and its radiation, may have kept fairly constant for long periods. We also conclude from this consideration that the nebular stage lasted a much longer time than Ritter assumed.

Ritter carried his calculations further under the hypothesis that the height of an atmosphere over a body resembling our Earth, that is to say, a body provided with a solid crust, would be sufficiently great to force us to admit different values of gravitation at different heights. He found that, if the temperature of the solid surface exceeded a certain value, the atmosphere of such

a cosmic body would have no limit ; gases would indeed escape from it. Carrying out this calculation for hydrogen, he ascertained that the Moon would only then be able to keep an atmosphere of hydrogen, if its temperature always remained below —85°. But the temperature of the Moon is nearly that of the Earth on average, rising to 150 degrees in the hottest parts. We cannot then credit the Moon with an atmosphere of hydrogen. In the same way Ritter proves that the Moon cannot have any water on its surface. The same argument would apply all the more forcibly to the asteroids, which are so much smaller than the Moon.

These speculations of Ritter have attracted many scientists, among whom Johnstone Stoney and G. H. Bryan are the most prominent. Both start from the laws of the mechanical theory of gases concerning the free movements of the molecule. According to Stoney the Earth would be unable to retain hydrogen gas in its atmosphere, and that is probably right. But helium too would in his opinion be endowed with far too high a kinetic energy to be retained by so small a body as the Earth. The calculation does not appear to favour Stoney's view. But we may imagine that helium had already left the terrestrial atmosphere at a very early period, when the temperature was much higher and its extension much greater.

Ritter's inquiry into the effects of a collision is of very great interest. Mayer had shown that a meteor, rushing into the Sun from a very great distance, for instance, from the distance of Neptune, and starting with an initial velocity of zero, would at the Sun's surface have attained a velocity of 618 km. per second, and would therefore increase the solar energy by 45 million calories per gramme of its (the meteor's) mass. In the collision between two suns an immense quantity of heat must necessarily be liberated. That heat may be spent in expanding the new body. If two equal suns were to rush against one another from infinite distance, likewise starting from rest without any initial velocities, the heat produced by their collision would according to Ritter suffice to expand the two masses of gas to four times their original volume. In order that the whole masses of the two colliding suns may be spread over infinite space, each of them should have an initial velocity of about 380 km. per second. Such a velocity sounds very great for what we call a fixed star. This speed would, however, appear to be surpassed by a small star of the eighth magnitude discovered by Kapteyn in the constellation Columba. This star is credited with a velocity exceeding 800 km. per second, and the giant sun Arcturus seems to move with a velocity of 400 km. per second. All the same, these high velocities may be very rare exceptions. But a

sun of a hundred times the dimensions of ours, colliding with a gas ball of similar dimensions, would only need an initial velocity of 38 km. per second in order to disperse its whole mass throughout infinite space, and to form what Ritter calls a "centrifugal nebula," which would continue to expand and to spread out further and further into space. "We may perhaps class the spiral nebulæ, due to oblique impacts, with the centrifugal systems." Strictly speaking the expansion would go on unlimited in all directions. But the gases might conceivably be checked and arrested in their movements and stopped by meeting material particles. Ring-shaped nebulæ might be formed in similar ways. Croll had required velocities of over 700 km. per second for two colliding suns in order to explain the production of solar heat; Ritter did not think that necessary. We may also lay stress upon the statement, that a gaseous nebula of the mass of the Sun and of a hundred times its radius without colliding with another cosmic body, merely by its own contraction to the dimensions of our Sun, might acquire a sufficiently high temperature to make it shine as a bright white star.

When the velocity with which the two cosmic bodies collide sinks below the value above stated, a centripetal system would arise, that is to say, a mass of gas which would gradually contract to a fixed star. According to Ritter this star might

periodically swell and contract as if oscillating about a position of equilibrium; in this way he seeks to account for the periodical fluctuations in the light intensity of variable stars. Such pulsating movements would soon be checked, however, by radiation; the changes in the light intensity of such stars, moreover, are not, as a rule, so regular as Ritter's calculations assumed. His view on this point has not met with general acceptance.

Ritter further believes that condensations into small stars take place in centrifugal systems. The condensation would lead to the formation of star clusters, and we have indeed reason to suppose that the spiral nebulæ consist to a large extent of such star clusters. Finally Ritter raises the question, whether the Milky Way might not possibly be such a star cluster originating from a centrifugal system. He says, however, that in that case the system of the Milky Way could not possibly make up the main bulk of the material in its immediate surroundings.

In order to attain so high an initial velocity, as would explain the formation of a centrifugal system by a collision, the two colliding masses of gas should, in his opinion, previously have been exposed to the attraction of still greater masses, and these forces should have continued to act.

Ritter thus concludes that centrifugal systems would only in rare exceptions result from the

collisions of two extinct stars, the condition being that the suns move at an extraordinarily high velocity. Nothing prevents us from assuming, however, that a comparatively small fraction of the solar system may be centrifugal, whilst the main mass is a centripetal system. The combination would be normal, as has been indicated above. The centrifugal system would form a spiral nebula about the centripetal as centre, and the latter would gradually be evolved in the manner which Laplace suggested for the nebula which became transformed into the planetary system.

Ritter has also calculated the periods which a fixed star of the size of our Sun would require for the different stages of its development. He distinguishes four periods. His first period is that of the nebular stage. The temperature is relatively low, the star shows first the nebular spectrum; afterwards it emits a reddish light. Several scientists, as, for example, Lockyer, incline to this view for theoretical reasons; but observations do not support it. The nebulæ show the bright lines of hydrogen and helium. But many stars give the same bright lines and should therefore be closely related to the nebulæ; they emit, however, a white, not a red light. It would, therefore, appear that the intermediate stage demanded by Ritter between nebulæ and white stars, i.e. nebular stars with red light, is missing. But it

may also be that such transitory stages, if extant, are very rare (compare "Worlds in the Making," page 185). Ritter, moreover, considers these intermediate stages as of insignificantly short duration by comparison with the period required for the transition from white to the red light.—There are many red stars of very high intensity, Beteigeuze, for instance; the red light of this star is presumably due to the absorption of light by the dust in its atmosphere or in its surroundings (compare "Worlds in the Making," pages 71 and 181).—The first period up to the maximum of radiation would comprise a space of 16 million years. The temperature afterwards rises—not sufficiently, however, to raise the total radiation at the same time, because the radiating surface is rapidly becoming smaller—until it reaches its maximum. This period is relatively short, about 4 million years only. The third period, during which the light intensity of the star is continuously diminishing and its temperature falling, may last some 38 millions. Then would finally follow the fourth period of very long duration, the lightless, extinct stage of the star. All these calculations are based upon the assumption that the heat of the Sun is merely due to its contraction, and they may, therefore, be altogether wide of the mark, because probably it is the chemical processes, and not the contraction, which constitute the chief source of heat.

Ritter's calculations lead to the result that a sun cannot be awakened to a new life by collision with a planet if the sun is itself already extinct. Kant's poetical dream of the revival of the solar system by the rush of the planets into the Sun can hardly be realised. "The accumulation of incombustible and already burnt matter," the celebrated philosopher says, "e.g. of the ashes on the surface, finally also the want of air, will end the existence of the Sun; its flame must once cease to burn, and the spot which is at present the centre of light and of life for our Universe, will some day be taken up by eternal darkness. The alternating endeavours of its fire to revive itself by the opening up of new caverns, whereby it might be restored several times before its destruction, might afford an explanation of the disappearance and the reappearance of some fixed stars." "We must not wonder to recognise perishability even in the grand work of God. Everything that is finite, that has a beginning or an origin, bears the imprint of its own limited nature. It must perish and must come to an end. Newton, the great admirer of God's qualities from the perfection of His works, who combined with the deepest insight into the excellence of Nature the greatest reverence for the revelation of Divine omnipotence, felt constrained to predict to Nature her own decay by the natural tendency of the mechanics of motion." "In the infinite course of eternity there must finally be

a moment, when this gradual diminution will have exhausted all movement."

"We need not regard the destruction of one Universe as a real loss in Nature, however. In another spot this loss will be made up by abundance." Kant imagined that whilst the suns were vanishing in the neighbourhood of the central body of the Milky Way, new suns would be rekindled in the remote cosmic nebulæ, and the number of inhabited worlds would always be growing. But Kant did not like the idea that our Sun and planets would lie dead for all eternity in the centre of the Milky Way. That seemed to him to be incompatible with reasonable rule. "If, in conclusion, we may give expression to an idea, which seems as probable as it is appropriate for the constitution of the divine work, then the satisfaction which such a picture of the changes of Nature produces in us will be elevated to the highest state of contentment. May we not believe that Nature, which could bring itself into order and a suitable system out of chaos, will as easily be able once more to renew itself out of the new chaos, into which the diminution of its movements has sunk it, to restore the former combination? Cannot the springs, which first marshalled into order and movement the substance of dispersed matter, by the aid of renewed forces be set into motion again after the machinery has run down? We need not hesitate to admit this possibility, when

we consider that, when the final fatigue of the orbital movements will have made the planets and comets all rush into the Sun, the glow of the Sun will receive an immense accretion by the admixture of so many and so large lumps, especially because the most remote balls of our solar system contain, according to our deductions, the lightest and the most fiery substance of all Nature." The renewed supply of fresh fuel would make the Sun flare up once more in violent conflagration and suffice to bring everything back to its original state, so that a new planetary system could be formed from the new chaos. This cycle would be repeated several times. Then the greater system of which ours forms merely a fragment, the system of the Milky Way, would in itself be brought to rest, to be revived again and to impart new life to formerly void space.

"When we follow this Phœnix Nature, which cremates itself only to rise rejuvenated from its ashes, through the infinity of space and time, the mind which ponders over all these problems sinks into deepest wonder."

We did not know the mechanical theory of heat then, and Kant who dimly felt that the glow of the Sun must be sustained by combustion (chemical processes) did not recognise the inconsistency of the assumption that the burnt-out matter could again and again create new energy by repeated recombustions. It would be unjust

to measure by a physical scale this beautiful poem in which Kant even divested himself of his usual style of writing. Under the criticism of natural science the magnificent conception of Kant in which the longing for the eternity of Nature finds so nearly true an expression shrinks to nothing. It is the grandeur of his system which excites our admiration, not its physical foundation. To work out the details of his scheme was not given to Kant.

Kant's idea was adopted by the spiritistic philosopher Du Prel (1882), almost unchanged, and yet in lighter garb, which permitted him to take account of the enormous strides that our knowledge of the heavens had meanwhile made and to avoid the naive teleological sentiment of Kant. He too makes the planets rush into the extinct Sun to revive it again. "We cannot believe that the corpses of stars should, like icy spectres, float through space until reunited with the central system which would finally be reduced to immobility by the resistance of the æther. We shall rather regard the primary nebula from which the star clusters were formed as the product of the reunion of all the stars of a cluster, whose motions, converted into light and heat, produced a temperature at which the total matter was retransformed back into a nebula—a cycle which reminds us of those "Kalpas," by which the Buddhists designated successive periods in the existence of the Universe, counting millions of

years and separated from one another by destructions."

A closer examination convinces Du Prel, however, that the whole Universe cannot be at rest at the same time; the life which dies in one spot will be blossoming out in its most beautiful shape in another. "Like Penelope who undid at night, what her busy hands had woven during the day, Nature destroys at times its works, and we have no right to ascribe to Nature the intention of completing the texture."

"After the destruction the development of every star commences afresh, and from our standpoint of terrestrial intelligence, the deep night of total oblivion will cover everything that might in a general sense be designated as the history of the defunct stars. No different race, no creatures destined for something higher will once become the heirs of the Earth, and nothing of all that mankind has achieved, will pass over into the hands of other beings." In agreement with Mädler, Du Prel regards the Pleiades as the central system about which our Sun is circulating. This view has, however, hopelessly been refuted by the researches of A. F. Peters.

"Thus we find in the cosmos, in proximity, all the phases of that eternal transformation in which gravitational movement is converted into heat, and heat into movement in space. Here swarms of flaming worlds radiating in their fullest splen-

dour, there fading star clusters, in which the variable stars indicate the period of decay, and the darkened suns attempt by a last effort to guard off the icy death. Whilst in one region the first suns begin to germinate in well-defined nebulous spheres, the delicately organised solar systems are, in other spots, once more carried out into space in the shape of diffused masses of gas. And ever anew recommences the Sisyphus labour of Nature."

Du Prel introduces the Darwinian conception into the consideration of the development of nebulæ into planetary systems or star clusters. The spheres of our planetary system enjoy marvellous stability. Thanks to their almost concentric orbits they are not threatened by collisions. Those which were less favoured as regards their trajectories have been colliding with one another, either to form new bodies with more favourable orbits, or finally to rush into the Sun. In this way those planets were gradually eliminated whose trajectories did not exclude the possibility of collisions, and we arrive finally at the actual, so extraordinarily fit system, whose stability is so wonderful that Newton deemed it necessary to institute a reasonable Being who had arranged everything from the beginning. This exposition of Du Prel's reads very acceptably. But it is nothing more than Kant's conception clothed in a modern, very beautiful and pleasing garb.

Du Prel rediscovers his own view in Lucretius in the following remarkable verses of his: De natura rerum, I, 1021-1028,

"Nam certe neque consilio primordia rerum
ordine se suo quæque sagaci mente locarunt,
nec quos quæque darent motusque pepigere perfecto,
sed quia multa modis multis mutata per omne
ex infinito vexantur per cita plagis
omne genus motus et cœtus experiundo
tandem deveniunt in talis disposituras,
qualibus hæc rerum constitit summa creata."

Which H. A. J. Munro has rendered:

For, verily not by design did the first beginnings of things station themselves each in its right place guided by keen intelligence, nor did they bargain sooth to say what motions each should assume; but because many in number and shifting about in many ways throughout the Universe they are driven and tormented by blows during infinite time past, after trying motions and unions of every kind, at length they fall into arrangements such as those out of which this our sum of things has been formed.

Roche has pointed out that, if the planets were some day to fall towards the Sun, because something checked their movement, as Kant and Du Prel imagined, they should, long before reaching the central body, be crushed by the unequal action of gravity upon the different parts—those near and those further removed—of the same planet. Biela's comet, e.g., was destroyed in this way when coming too near the Sun. During this annihilation violent

volcanic eruptions would no doubt raise fragments of the planet to a temporary incandescence, even if the Sun were already extinct. That glow would, however, be too faint to be noticed outside our planetary system. If the Sun were not extinct, the planet would doubtlessly melt into a fused mass of doughy consistency, from which pieces would separate without any violent disturbances. In any case the planet would finally descend quietly upon the Sun in the shape of meteoric dust, and there would be no change in the physical state of the Sun. We may admire the story of the creation according to Kant and Du Prel; but we cannot credit it with a physical foundation. Their system would have to be realised in other modes than those proposed by them.

IX

THE CONCEPTION OF INFINITY IN COSMOGONY

WHILE we have so far chiefly dwelt upon scientific problems, we turn now to the more philosophical question of the conception of infinity. A star like Sirius may be ever so far removed. There will be stars still further off, and when we at last think that one star must be the very last and most remote of all, we cannot but imagine the space beyond it to be continued. We cannot conceive a limit to space any more than a limit to time. However far back we may carry our ideas, we shall still be confronted by the thought, that there must have been a time before that particular moment. Nor can we conceive any end to time. Space is infinite, and time is eternal. But it is equally impossible to grasp the idea of infinite space and of infinite time. Hence man has attempted to picture the Universe as finite, and time as starting from a beginning. We remember the Babylonian creation myth.

The view that space might be finite, although

apparently infinite, has strangely enough found various and ingenious advocates, among others the great mathematician Riemann and the great physicist Helmholtz. The surface of the sea appears to us curved, because the Earth is a sphere, and of an island which is some miles distant we see from the opposite shore not the beach, but only the tops of the trees and the crests of the mountains. At times, however, peculiar atmospheric conditions occur under which the opposite shores become visible to us. If the atmosphere were throughout of the same density, the rays of light traversing it would be perfectly straight lines. But the density of the air increases from above downwards at a rapid rate, and light is refracted in the air almost as if it were passing through a prism. This increase of density in atmospheric strata may, under certain conditions, be such that a ray of light, which issues parallel to the surface of the Earth, is so refracted that it always remains parallel to it and assumes the curvature of the open sea. A person looking straight towards the horizon would in that case look right round the Earth, so to say, and be in a position to see his own back. The man would, of course, not be able to discover himself in this way; but the Earth or rather the sea would appear like a smooth plane extending to infinity in all directions.

We might now fancy that light rays, coming to

us from space, should also be curved for some reason or another, so that, while apparently gazing upward, we should be looking around the Earth and finally see objects really visible only from the other side of it. It would not be possible to us, it need hardly be pointed out, to see the Earth itself in this (false) line of sight ; because the path which the light would have to describe on its way from the other side of the Earth up to our eye would be of immense length, longer than the distance of any visible star. Nor should we be able, as might easily be proved, to see any stars further removed from us than the extreme points of that circular path which the ray of light would have to describe.

Although we should therefore only see that portion of the Universe, which lay within a certain distance—very great indeed, but of a definite limited length—we should yet fancy that we were looking across the Earth in every direction, straight into infinite space. We could not hence assert that space was infinite, at least not so far as we relied upon our own perception.

Helmholtz wished that this possibility should be examined by astronomers. As our observations do not suggest anything of the kind, the examination appears to be rather superfluous. For we cannot imagine any cause which would vary the density and refractive power of the æther in space in the same manner, as tem-

perature may affect the density and the refractive power of our atmosphere so as to produce a curved ray. It seems unnatural to assume that the line of sight could gradually become curved in space. All these notions which excited considerable attention for some time after the middle of the last century have almost completely been abandoned, all the more so because the idea proved barren in scientific respects. People interested in this particular question will find critical reviews in the works of the Dane Kroman and of the American Stallo, as well of the French mathematician Poincaré. We are satisfied with the old, simple notion.

Whether or not the number of stars is infinite is an old controversy. Anaximandros, Demokritos, Swedenborg, and Kant regarded it as infinite. If the stars are to be fairly uniformly distributed in space and not strongly crowded there, where our Sun is placed, the whole sky would glow in the splendour of the stars, more intensely still perhaps than the Sun, and everything on the Earth would be burned. This conclusion was drawn by Olbers in 1826. (We assume that all the cosmic bodies would have the same average temperature as the fixed stars, which on the whole appear to be warmer than the Sun.) But the Earth is not being consumed by fire, and we have only two reasons to account for that. Firstly, the stars may be concentrated in the

immediate neighbourhood of our solar system and become the scarcer, the further away from it. It is strange that most astronomers are inclined to accept this very unphilosophical view. The demonstration of the radiation pressure has disposed of that notion. For owing to that pressure all the stars would in the infinite course of time have been dispersed through the infinity of space, if really they should ever have been concentrated about a certain centre, such as the middle of the Milky Way.

If this first argument is not valid, we have to consider the other possibility, that a great number of dark celestial bodies of extremely low temperature and immeasurably larger than the visible stars may be existent in space. The cold nebulæ are such bodies. They cover a very much greater portion of the sky than the fixed stars. The light which we receive from all the stars together amounts to one thirty-millionth part only of the light that the Sun sends us. If we assume equal brightness per unit area in the two cases, the area covered by all the fixed stars which we see would be less than 0·1 square second of arc. A big planetary nebula, No. 5 in W. Herschel's catalogue, situated near the star B in the Great Bear, has a diameter of about 160 seconds of arc, and covers consequently an area 260,000 times greater than that of all the fixed stars. In addition to the planetary nebulæ we have the irregular

nebulæ, e.g. that of Orion, which possess a very low density, but extremely large extension. It is on account of this prevalence that we ascribe so great an influence to the nebulæ. They possess the strange property of expanding and cooling by absorbing radiated heat from outside. When they expand, those molecules of gases which possess the greatest velocities are expelled and are replaced by masses of gases from the interior, more concentrated portions of the nebula. Under a diminution of entropy greater and greater masses of energy are in this way accumulated in these streams of gases which collect on neighbouring stars (compare " Worlds in the Making," page 191).

Thus there remains no other conclusion but that the number of stars in infinite space must be infinite. We are far removed yet from knowing even all those which are not obscured by other bodies that stand in our line of sight. The more our optical apparatus are perfected, the more new universes with crowds of stars open up to our eyes. But their number does not increase in the same ratio as the space which those instruments resolve. The ratio is far less, and that may partly be due to the obscuring action of the dark bodies.

That matter is imperishable or eternal was dimly felt by the primitive races in their creation myths. The original assumption was a chaos or primeval water which had been existent from all

eternity. Riper thought led then to the philosophical views of Demokritos and Empedokles. But during the Middle Ages metaphysical notions began to rule. Matter according to them originated from nothing by an act of creation. We meet with this idea in Descartes—though we are not certain of his believing in it—in the immortal Newton, still even in the great philosopher Kant, and much later in Faye and C. Wolf. Yet we can trace the leading idea of a gradual development of matter under constant preservation of its quantity through all cosmogonies. There is a strange inconsistency in the notion that the world could suddenly have begun to exist. We cannot expect that one single man should solve the whole totality of the cosmic problem, and we can very well understand, therefore, why Laplace should say, he only intended to demonstrate, how a certain portion of the development had taken place, and to leave the rest to other scientists. Instead of imposing upon themselves some such simple restriction, people have often jumped at supernatural explanations. They abandoned the clear rule of the constancy of the laws of Nature which Spinoza had laid down (page 48).*

* The great philosopher Spinoza was born in 1632 in Amsterdam, and he died at the Hague in 1677. His fate proves that civilisation has made enormous strides since that time. It may, therefore, be briefly related here. His parents were Portuguese Jews, whom the persecutions of the Inquisition had driven to Holland. The extraordinarily gifted young man could not

Herbert Spencer is equally clear on this point. He declared that we cannot believe the visible world to have either beginning or end. When Spencer said this, he knew the doctrine of the indestructibility of energy (it was called force then) quite well, and he was, of course, familiar with the thesis of the indestructibility of matter, which had been demonstrated by Lavoisier and which had tacitly been accepted before, although not clearly understood. During the last decades the question has been asked, whether matter (as determined by weight) might not be destroyed after all. With the utmost care, Landolt has conducted series of experiments upon the constancy of weight during the chemical reactions between two substances. He did in a few cases observe some insignificant variations of weight and apparent losses of matter, greater than the experimental errors. Continued experiments have, however, convinced him that those variations of weight were only apparent and to be explained by slow changes in the volume of his vessels due to a rise of temperature during the reactions. We are therefore experimentally justi-

refrain from questioning some religious dogmas of the Jews of his time, and he was therefore harshly dealt with by his fellow-believers. Finally they endeavoured to persuade him, under promise of compensation, to give apparent recognition to the Jewish tenets. The offer was refused with scorn. His life was then attempted, and he was expelled from the Jewish community. Afterwards he supported himself by grinding optical lenses while writing his grand philosophical works.

fied in saying: the manifold experiences of chemists entirely confirm the view of the old philosophers that matter is indestructible.

It is strange that learned men, who are ready to concede a sudden origin in dealing with cosmogonical problems, do not in their systems ascribe any time limit to matter. This inconsistency is really incomprehensible, as incomprehensible indeed as if we were boldly to assert that the stars to the north of the ecliptic were infinite in number, but not those to the south of it.

It might be objected that under certain circumstances physicists speak of infinity in one direction reckoning from a certain point, but not of a continuation of infinity in the opposite direction. Thus we count the degrees of temperature upwards from absolute zero, but we do not count any degrees below that point. The objection can be met. It would not be impossible at all to imagine a scale of temperature, which involved the assumption of a negative infinite temperature. It would be sufficient, for instance, to base statements of temperature upon the logarithms of temperatures reckoned from $-273°$. On the other hand we have to admit, that temperature is probably due to molecular movements, that a movement in the negative sense would be perfectly equivalent to a movement in a positive sense, and that it is for this reason impossible to go below absolute immobility. Nor can we any

better conceive negative matter. But a negative, that is to say, a past time, we cannot only conceive, but we must conceive it, and it is therefore quite inconsistent to speak of the eternity of matter in the future, but not of its eternity in the past.

Spencer has pointed out, as already mentioned, that it is just as impossible to imagine a creation of energy or force, as a creation of matter. "Force can neither arise out of nothing, nor lapse into nothing." On this point the philosophers had shadowy ideas to which the advance of natural science has given better expression. In the writings of Descartes, Buffon, Kant, as indeed in all older cosmogonies, we meet with many traces of a dark presentiment of the indestructibility of energy. Descartes and Kant insisted that to maintain the glow of the Sun some fire was necessary for whose sustenance the presence of air was regarded as indispensable. Buffon thought even that the other suns, which likewise emit heat continuously, sent to our Sun as much light as they take from it. He thus suggested a kind of thermal equilibrium. Unfortunately he did not examine the problem any further.

A clear insight into these relations was only given, at the beginning of the past century, by the genius of Sadi Carnot. But some of his work remained unedited and unknown owing to his untimely death, and the principle of the indes-

tructibility of energy had to be revived by Mayer, Joule and Colding, and to be worked out by Helmholtz. It is very significant that not one of these men was a scientist by profession, though Helmholtz was an eminent mathematical scholar. Carnot and Colding were engineers, Mayer and Helmholtz medical men, Joule a brewer. If we look more closely into the causes of the discovery, we find principally philosophical arguments, and sharp attacks have indeed been directed against these pioneers, because their views were too philosophical. Scientists had long held the opinion that heat was due to motion of the smallest material particles. Expressions to this effect we find in Descartes, Huygens, Lavoisier and Laplace, Rumford, and Davy. Another school regarded heat as one of the "imponderables." The founder of the mechanical theory of heat had in a certain sense already gained a clear grasp of the former assumption. But Carnot was chiefly interested in considerations concerning the nature of caloric engines, in which work is done by heat passing from a warm body to a cold body. In a transformation of heat, such that maximum work is performed, the quantity of work should in all cases, according to Carnot, be independent of the heat transferring medium, provided that the warm body and the cold body were all the time kept at the same temperature. This principle may also be

expressed by the statement, that the "perpetuum mobile" is impossible. In this phrase we recognise the firm conviction of the engineer that no work can be produced from nothing. Mayer's treatise teems with expressions such as: from nothing comes nothing; he had imbibed the idea of the substantiality of work. Colding wrote that it was his firm conviction that the forces of Nature, which we found here, as well in the organic, as in the inorganic world, in plants and animals as well as in lifeless Nature, had not only been in existence since the beginning of the world, but that these forces must always have been at work, in developing the world in the sense which was imparted to it at the creation. Joule says in a popular discourse: "We may conclude a priori that an absolute annihilation of the *vis viva* $\frac{mv^2}{2}$ cannot take place; for we cannot assume that the force with which God has endowed matter can be destroyed or can be created by human activity." Helmholtz's treatise which came four or five years later, is to-day regarded as a physical memoir of the first order. Then, however, the most prominent scientific journal, "Poggendorf's Annalen," refused to accept it, as it had declined to publish Mayer's treatise. We see plainly that the physical importance of these investigations was not understood. They were merely regarded as philosophical speculations. Those very researches have become the foundation of the extraordinary

reform which not only physics, but chemistry and physiology have undergone during the past century. The indestructibility of energy and its existence from eternity to eternity has been established once and for all.

Strangely enough the development of this branch of science carried with it the germ of the negation of the principle of eternity. The theory of heat postulated that heat should by itself, that is to say, as long as no work was being performed, always pass from the warmer to the colder body. As a consequence the development of the world would proceed in the sense that all energy would gradually be transformed into molecular movement, and that any temperature differences in the Universe would tend to equalise. That done, all motion must cease with the exception of the molecular movements, and all life must become extinct. That would be the complete Nirwana of which the Indian philosophers were dreaming. Clausius has designated this final state of thermal equilibrium "Wärmetod" (heat death). If the world really tended towards thermal extinction, we do not see why this fate should not have befallen the world already in the infinite ages through which it has manifestly passed. And since we convince ourselves every day, that the world has not yet been struck by this fate, we should consistently conclude, that the idea of eternity has no real basis, and that the world cannot have been

existent for unthinkable ages, but must have had a beginning, i.e. that it must have been created, and that the creation gave us both matter and energy. By his "degradation of energy" Lord Kelvin has lent his authoritative support to the doctrine of thermal extinction. Yet the doctrine implies the absolute negation of the idea of eternity which is the foundation of the mechanical theory of heat. We must look for some way out of this difficulty.

The Universe is undoubtedly passing through a development. If that development always took place in the same direction, it would finally come to an end. If an end is not attained, the reason can only be, that the development is not tending towards a final standstill, but that it involves a kind of cyclic movement. A hint of such a view, though very obscure indeed, is found in Kant. He speaks of the "renewal" of the burnt-out suns "in mixing with chaos" by expelling the finest and most volatile matter of the Sun into the Zodiacal Light, which he regards as a remnant of chaos.

We quote the following remarkable sentences from Kant. "If now creation is infinite with regard to space, the Universe will be alive with worlds without number and without end." Further on he discusses, how the suns have become extinct, how the worlds moving about the central body which he assumes to be in the visible Universe

will perish to be reawakened to life at far distances, so that the number of living worlds is constantly growing. "But what becomes of the matter of the destroyed worlds? May we not believe that Nature, which was once able to arrange herself to so fitting a system, might once more step forward and renew herself out of the new chaos in which the disappearance of all motion had immersed it? We shall no longer hesitate to admit this." Kant believes that when planets and comets are rushing into the Sun, matter is expelled by the heat thus created in all directions, and by the consumption of this heat a new planetary system will be formed resembling the old one. In a similar manner the immense system of the Milky Way will collapse some day and be restored. Such processes, he believes, may be repeated "to fill eternity as well as all infinite space with their wonders." This grand speculation unfortunately lacks a physical foundation (compare page 214). Croll suggested, in 1877, that the regeneration of the original nebula required the collision of two extinct suns. This path, which later scientists like Ritter, Kerz, Braun, Bickerton, and Ekholm have taken, leads us to the conclusion that the whole Universe tends to aggregate into one cold dark mass. If we are to escape this conclusion, we must look for forces which disperse matter.

Herbert Spencer (1864) is most precise on this point. His argument is the following: There is

a co-operation of forces in the development of planetary systems, forces which tend on the one side to collect matter and on the other side to disperse it. The collective forces predominate during that period of development which is characterised by the transformation of nebulæ into the suns, planets, and moons. Some day, however, the diffusive forces must gain the upper hand, and the planetary system will then return to the state of attenuated nebula from which it had grown. Long periods of collective forces will alternate with extensive periods in which the dispersive forces will predominate. When matter is collected, motion is dispersed, and when motion is absorbed, matter is dispersed. Rhythm characterises all movement. Spencer believed evidently that in the concentration of matter by virtue of the mutual approachment of the bodies potential energy was lost; by the diffusion of matter potential energy was stored up again—the inverse relation would apply for the energy of motion. Nietzsche has expressed himself in a similar way.

Spencer is certainly right in the main. But as the physicists of his time did not know any dispersive forces, such as Spencer postulated, his words remained unheeded. Those forces are well known now. They are chiefly accumulated in the explosive compounds which form in the innermost portions of the suns at highest pressures and temperatures. To this is to be added the heat

absorption by the dust contained in the thin gas envelopes during the nebular stage; by virtue of the accelerated molecular movements gases are expelled in all directions, and will finally augment the energy of the masses, especially of the stars, in their neighbourhood. This process counteracts the so-called increase of entropy, or with other words, the equalisation of temperature between different bodies of the Universe, and it delays the Wärmetod (compare "Worlds in the Making," pages 194–211). We have further the radiation pressure which carries the particles away from the suns through all space.

The new conception of the indestructibility of matter imposed upon natural scientists new problems to be solved. They had to ask themselves, how the Sun could waste its energy without, it seemed, becoming noticeably colder. Mayer gave the answer that the solar heat was maintained through the inrush of meteors into the Sun. That this source of energy would be entirely inadequate has already been pointed out at length (compare "Worlds in the Making," page 67). This holds also for the modification of Mayer's thesis given by Helmholtz, according to whom the whole mass of the Sun would sink towards the centre of the Sun, or that the Sun would become warm by contracting. This view of Helmholtz is still quoted in support of the theory of Laplace, according to which the Sun is the result of the contraction

of a vast nebula. We have already explained that on this supposition the Sun could not have been radiating heat at the present rate for more than 20 million years.

Geologists, however, would not listen to such estimates. They demanded for the deposition of the earliest Cambrian fossil-bearing strata something of the order of a hundred or a thousand million years, whilst perhaps 100,000 years must have passed since man first walked on the Earth. The demand led to a violent controversy between geologists, biologists, and physicists, especially in England, where several physicists sided with the geologists. The contest was, of course, decided in favour of the geologists, who had positive statements to rely upon, whilst their opponents chiefly brought up the negative argument, that they could not say where the Sun might under such circumstances have found the source of its energy.

I have endeavoured to elucidate this problem by pointing out that chemical reactions may liberate all the more heat, the higher the temperatures at which they proceed. Let us consider, for example, what will occur when the temperature of one gramme of ice is gradually raised from —10°. At the freezing point the ice will liquefy and will absorb about 80 calories. At 100° it will evaporate and absorb 540 calories. At still higher temperature, about 3,000°, water vapour will dissociate into hydrogen and oxygen, under a

further consumption of about 3,800 calories. Our experimental means then fail; we cannot produce any higher temperatures. But it would be wrong to assume that chemical processes must cease because our apparatus fails. It is very probable that at very high temperatures hydrogen and oxygen are split into their atoms under consumption of hundreds of thousands of calories. Now, it might be said, we have come to the end of the chemical processes, since atoms cannot be decomposed any further. The answer of science is: No! The atoms may enter into combinations which absorb enormous quantities of heat. A few years ago Curie discovered that radium continually evolves heat. It has been found since then, that radium compounds generate helium under liberation of about 2000 million calories per gramme of radium. At higher temperatures this process must take place in the inverse direction under consumption of this simply inconceivable amount of energy. We have been studying these phenomena only for so short a time that we cannot speak with anything like full clearness. But there is nothing against the assumption that, at still higher temperatures, chemical processes will take place which require much greater quantities of heat per gramme of matter entering into combination. The epoch-making chemical discoveries of Rutherford and Ramsay leave our fancy almost free play in this question.

At ordinary temperature the radioactive bodies are decomposed; at higher temperatures they are re-formed from their decomposition products, when the latter are present in the requisite quantities. The higher the temperature, the smaller the quantity of these decomposition products, and at sufficiently high temperatures the latter will scarcely be existent any more. According to the researches of Strutt this condition would occur at relatively low temperatures, such as we assume for a depth of about 70 km. under the surface of the Earth. Strutt attempts to explain the fact that the temperature increases as we penetrate into the depths of the Earth, by the assumption of a gradual decomposition of the radium contained in the Earth crust. In the common rocks which make up this crust he found on an average eight grammes of radium per million cubic metres. If the whole Earth should, on an average, contain as much radium, that radium would by its decomposition liberate about 30 times as much heat as the Earth is actually losing by radiation into space. We cannot very well assume, that the radium is confined to that portion of the Earth which is formed by the crust of 70 km. thickness and which constitutes the one-thirtieth of the whole globe. We therefore have to consider the probability that at still greater depths radium will be formed from its decomposition products,

if present there in sufficient quantities. The temperature would have to be something like 2000°. At a certain temperature uranium must also be formed from its decomposition products, one of which is radium. For these reasons we need not be surprised that radium has not been discovered in the solar spectrum, as we assign a temperature of more than 6000° to the Sun.

No quantity of uranium worth mentioning is produced from its decomposition products at ordinary temperature. According to Rutherford, uranium is being decomposed at a rate such that in 7000 million years only half of it would remain. Rutherford further concludes that a cubic centimetre of helium is formed from one gramme of uranium at a pressure of 760 mm. and 0° within 16 million years. Now a certain mineral, fergusonite, contains 26 cubic centim. of helium per gramme of uranium. We may hence assume that the uranium of this mineral will have been decomposed in the space of 26 times sixteen million years, that is to say, in 416 million years. So long a space of time must have elapsed since this mineral could have been formed from the glowing masses thrown up from the interior of the Earth (compare "Worlds in the Making," page 43).

The masses of radioactive minerals, which are ejected by a sudden eruption from a sun and then cool down in space, will of course emit radioactive rays in abundance. There may be also

present radioactive compounds which are rapidly decomposed, and which we do not know on the Earth, because they would long since have been transformed. But it is not at all improbable that the strong radiations, which are observed from the nebulous portions surrounding new stars, may partly be radioactive in nature; they need not entirely be due to electrically charged dust particles repelled by the new star.

The nebula formed at the time of the flashing-up of a new star loses its helium by absorption of radiation from space. The helium is condensed upon cosmic dust and thus wanders back into denser materials. By the concentration of the matter the temperature of these parts is increased, and strongly radioactive bodies are once more formed. It is similar with other explosive, though not radioactive, compounds. The nebulæ thus collect, not only the particles of dust which drift into them and other matter which had been expelled by the Sun and transported by the radiation pressure, but also the energy which had been radiated into space. These stores of dust and of energy are gradually accumulated in those portions of the nebula which are nearest its nucleus, and especially in the interior their temperature will be high. There they are re-transformed into radioactive and explosive compounds endowed with enormous energy; and when the Sun into which the nebula had turned once more begins to lose

more energy by radiation than it receives from outside, these bodies will gradually be re-decomposed during the subsequent slow fall of temperature. The vast stores of energy, however, will retard this cooling and maintain radiation at an almost constant rate during the course of thousands of millions and even millions of millions of years.

It will be granted that in this way nothing need be lost of energy, nor of matter, in the Universe. The energy which the suns lose is re-found in the nebulæ, which in their turn play the part of the suns. Thus matter passes through a continuous cycle of stages of energy absorption and energy emission. Nothing more is required for this purpose but that the masses of gas situated in the colder parts of the nebulæ and the particles of dust which have immigrated should absorb the immense amounts of energy which were lost from the suns by radiation. The little that a few years' study of radioactive phenomena has taught us indicates that small quantities of matter are capable of concentrating in themselves stupendous stores of energy.

We must now regard the interior of the Sun as a heat magazine of this kind. During its cooling the chemical reactions proceed in the inverse sense as during the contraction, and great quantities of heat are liberated which will amount to several billion calories per gramme. Since now every

gramme of the Sun's mass loses on an average only 2 calories per year by radiation, it is evident that this process may continue for billions of years. It may also have continued for long periods in the same manner, without any noteworthy diminution, during the thousand million years which geologists demand for the existence of life on the Earth. It is certain that the oldest known organisms which have left traces in the fossils of the Cambrian Age must have lived under temperature conditions which did not much differ from those of the present day. These organisms had reached so high a degree of development that we may surmise that the period which elapsed between the first appearance of one-cell organisms and the time of the Cambrian Age must be as long at least as that which has passed since the Cambrian Age. The organisms embedded in still more ancient geological strata were either too perishable to be preserved in the fossilised state, or they have been destroyed in the course of time under the influence of the enormous pressures and high temperatures, or of both combined, to which those strata must have been exposed for millions of years.

Having thus convinced ourselves of the physical possibility and the reasonability of the cyclic character in the changes of the Universe, by contrast to the " thermal extinction " of Clausius or the " degradation " of Kelvin, we will now turn to consider some special points which have come up

during this discussion. We will proceed graphically, and since we cannot apply our consideration to the whole infinite Universe, we will confine ourselves to that portion of the Universe which permits of observation. This portion is so big, however, that in its complex composition of nebulæ, cosmic dust, dark masses and suns, it will probably deviate little from that of other portions of similar size. We shall probably be able to apply the conclusions which we draw with regard to the part under examination to any other part of the Universe, and hence to the whole of infinite space. We shall first try to find an expression for the total deviation of temperature from the mean temperature of that space. For instance, let the average temperature of the Sun be ten million degrees and the average temperature of matter in that portion of the Universe under examination one million degrees. Then the deviation of the solar temperature from the mean temperature will amount to nine million degrees. If we multiply this figure by the mass of the Sun, we obtain the share of the Sun in the total deviation. To be exact we should, however, divide the Sun into two parts, an inner one whose temperature will be more than one million degrees, and an outer one with a temperature below that average, and we should calculate for each of these parts the partial product of mass and deviation from the mean temperature, and then form the

algebraic sum of the two terms without regard to their signs, plus or minus.

We apply the same procedure to a nebula, for instance, to the great nebula of the belt of Orion. In this case the product will no doubt have a negative sign, since the nebulæ are cold. After having performed this operation for all stars, nebulæ, planets, and for drifting masses of dust and of meteorites, we sum up the products thus obtained. The sum, which will be of huge magnitude, we call A. In our diagram the future is plotted as positive, the past as negative, and the present corresponds to the zero line (Fig. 28).

What will happen? Let us first follow the reasoning of Clausius. According to the law of entropy temperature tends towards equalisation, that is to say, the total deviation, which is A at present, will be less to-morrow, and within a certain time, say, in 10 million years, will have diminished to B. The process goes on; but since the temperature differences will be smaller than before, the equalisation will proceed at a slower rate. The curve which marks the change of A in the course of time will therefore be less steep beyond B than it was in starting from A. Though there will be a further fall in any case, the total deviation from the average temperature will become less, finally, as the mathematician says, to approach the zero limit asymptotically. After a sufficiently long time the deviation will have any small value

imaginable or, in other words, after an infinitely long space of time its value will become zero.

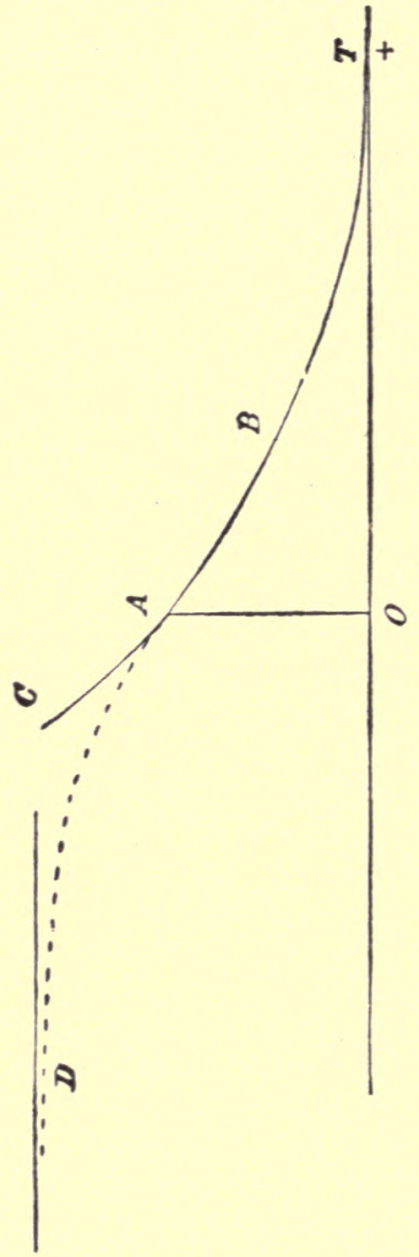

FIG. 28.

Now let us go further back in time. For reasons indicated the A curve must then have been steeper than at present. At a certain time, say 10 million

years ago, the total deviation was C, and if we carry our consideration back far enough, it may have had any value whatever greater than A. The mathematician would say that infinite ages ago the deviation must have been infinitely large. That, however, could only be the case if certain portions of the Universe, which are not visible to us, had an infinitely high temperature, and that again would involve that the average temperature and therefore the energy must have been infinitely large an infinitely long time ago. That is inconceivable in itself; and since we know in addition that the energy within the respective portions of the Universe must have had a finite, although certainly very large value, and that the total quantity of energy is invariable, it cannot a long time ago have exceeded any imaginable high value.

That hypothesis is hence untenable. Some physicists have attempted to find a way out of this difficulty in the following way. Though the inequality of temperature might conceivably, in past ages, have been greater than now, the equalisation may have proceeded at a slower rate, for instance, along the curve D A in Fig. 28. The temperature deviation would then have diminished at infinite slowness at first, afterwards, starting from a finite value at D, more rapidly, to proceed at a great velocity just at present, and to diminish again down to zero finally.

In other words, the world would have been lying dead for countless ages, just to develop with an amazing rapidity in the ages, with which geology and palæontology acquaint us, gradually to fall back again into the eternal inactivity of death. In order to show that this hypothesis is unthinkable and contrary to all scientific reasoning, Christiansen has suggested the following consideration. A heap of gunpowder may lie for a long time without undergoing any visible change. Somebody sets fire to it, or lightning ignites it; the powder flashes up, and the so far extraordinarily slow changes suddenly become so accelerated owing to the high temperature that an enormously rapid transformation is accomplished within a fraction of a second. There follows a slower chemical reaction, which will last for a few minutes and during which the products of combustion will react with the moisture of the atmosphere. That seems to be the end. The fraction of a second, utterly insignificant by comparison with eternity, during which the powder was flashing up, would correspond to that period of the evolution of the Universe about which we know something. But hardly any scientist will accept this comparison after a closer examination. There is, for instance, the difficulty that powder, as chemists teach us, is subject to slow changes even at low temperatures, changes which would be reduced to zero value only at absolute

zero temperature. Nor can we imagine that the world might, in previous ages, have developed at an extraordinarily slow rate, because the average temperature had been very low in those days. That assumption would be quite unjustified. On the contrary, we should in that case, as Christiansen recognises, have to assume that forces so far unknown in Nature had come into play in the evolution of the Universe. "That possibility lies completely without the range of our experience." It is impossible to argue on those lines.

We might deal with entropy in a similar way. The deduction would be more strictly scientific, but also less plausible. So far as the evolution of the Universe is concerned, the result would be the same. The deviation from the mean temperature in that portion of the Universe which we consider will have kept fairly constant in the course of time. With our Sun the deviation decreases gradually; but that diminution is compensated for by the rise in temperature which accompanies the transformation of a nebula into a star.

That conclusion also holds for entropy. Its value must on the whole have remained almost unchanged. On the one hand it is continuously decreased by the radiation of the Sun towards the cold nebulæ. On the other hand it is increased by the departure of the most rapid molecules of the light gases of the nebulæ and their accumulation upon the denser aggregates of matter.

If we again confine ourselves to a small portion, like our solar system, of the whole Universe, we have to consider that its average temperature is by no means constant. At the present time it is diminishing. This diminution must finally become very slow, when the Sun will be extinct; and some day when the extinct Sun will have been changed into a nebula by a collision, the diminution will turn into a temperature increase which will continue for a long time after the re-initiation of the solar state.

Thus Spencer's suggestion of a continuous periodical change in evolution holds for every separate solar system. But we cannot speak, with him, of a rhythmic change. For the respective periods in the Universe of suns will no more be regular than those of the oscillating movements of molecules. Length and events of the period will be dependent upon the collision with another body, sun or molecule, which is subject to accidental circumstances, and those features will affect the later development.

It is peculiar to see how the time idea has gradually altered. The above-mentioned estimate of Cicero, according to which the Chaldæans were said to have conducted astronomical observations for 340,000 years, shows that in antiquity man was not startled by the idea of a very long pre-existence of the Earth. Indian philosophers believed in countless ages. During the Middle

Ages that belief was entirely lost. Rhabanus Maurus states in his great work "De Universo" (at the beginning of the ninth century) that the fossils which were found high up in the mountains came from three great universal floods; the first at the time of Noah, the second at the time of the patriarch Jacob and of his contemporary King Og, the third at the time of Moses and his contemporary Amphitryon (a mythical grandson of Perseus). The age of the world was then estimated very low indeed. Snyder relates in "The World Machine," that Bishop Usher, the contemporary of Shakespeare and Bacon, had calculated from the Jewish chronicles, that the world had been created 4004 years before the beginning of our era, in the first week of January, and that date is to be found printed in English bibles up to the present day. Buffon calculated the time required for the cooling of the Earth from the state of incandescence, which it was supposed to have possessed at the moment of its separation from the Sun, down to its actual temperature. His estimate was 75,000 years. Our studies of the excavations made in Babylon and Egypt prove that a rather high state of civilisation prevailed over there 7,000 or 10,000 years before our era. The coloured outline pictures which are found in the grottoes of the so-called Magdalenian period in Southern France and in Spain, and which are very true to Nature, are credited with an age of about

50,000 years, and the most ancient finds unquestionably of human origin may have an age of 100,000 years. Man was certainly in existence before and during the glacial periods which visited the northern portions of our continent several times at the conclusion of the Tertiary Age. And lastly geologists believe that life in highly developed state must have been in existence for a thousand million years, and that the first signs of life made their appearance possibly twice as long a time ago. We thus approach the high figures which Indian philosophers suggested for the development of life on our Earth.

We have come to our last question, how the conception of eternity can be applied to the existence of life. On the whole naturalists incline to the belief that live matter owes its origin to physical and chemical forces such as are now at work on the Earth. In this respect the opinion of the majority does not essentially differ from that of primitive races (compare Chapter II). Others teach that life came to the Earth from space. We meet with this belief in the Norse legends, in the narrative of the immigration of several gods and of a human couple from the grove near Mimr's well (which corresponds to universal space). That opinion has found many eminent adherents, among them the distinguished botanist Ferdinand Cohn and Lord Kelvin, perhaps the greatest physicist of our age. The great

difficulties which so far attached to this view, I have tried to remove by introducing the radiation pressure as impelling power for the transport of germs through infinite space. That this thesis has found support, in spite of the great difficulties with which it had itself to struggle, is accounted for by the fact that people finally grew tired of refuting over and over again the statement, which was proclaimed every year with the same exultation, that somebody had after all succeeded in calling forth life from dead matter without the intervention of germs. The question is in about the same stage as the problem of the "perpetuum mobile" was half a century ago. The problem of spontaneous generation in its actual form, will, it is to be expected, be deleted from the scientific programme, just as the "perpetuum mobile" has been discarded. There is hardly anything left to us then, but to assume that life came to the Earth somewhere from space, i.e. from formerly populated worlds, and that life itself is eternal like matter and like energy. Yet for the present there remains one very essential difference which renders it difficult to establish the eternity of life. We cannot measure life in its various aspects quantitatively as we measure matter and energy. It is evident that life may suddenly be annihilated without necessarily giving rise to other life. Buffon had his own peculiar views on the indestructibility of the "life-atoms."

To detect means of measuring the quantity of life would be a revolutionary discovery which may never be made. We can yet comprehend the eternity of life. There will always be in the eternal cycle of Nature cosmic bodies favourable to life which will certainly harbour living beings. We may hope that the thesis of panspermia will conquer. If it prove victorious, it will have a very important bearing upon biological science, just as the doctrine of the indestructibility of matter has become most fruitful for the further development of exact science in recent years.

One important conclusion we may already anticipate. It is that all living beings of the Universe must be related to one another, and that when life begins on any body of the cosmos, it must commence with the lowest known forms to rise in slow evolution to more highly organised types. The albumins must under all conditions form the material basis of life, and notions such as that there may be living beings upon the Sun, must for ever be relegated to the domain of phantasms.

Most of the philosophers have been adherents of the eternity of life and opponents of the doctrine of spontaneous generation. It will be sufficient to recall in this connection the above-mentioned words (compare page 48) of the philosopher Herbert Spencer, to whom we are perhaps more indebted than any one else for

elaborating a consistent philosophy of evolution. Another remark of his runs as follows :

"The hypothesis of special creations (living beings rising from lifeless matter or from nothing) cannot be formed into coherent thought. It is one of those illegitimate symbolic conceptions, so continually mistaken for legitimate symbolic conceptions because they remain untested. We cannot elaborate the idea into something like definite shape. . . . Those who entertain the proposition that each kind of organism results from a divine interposition do so because they refrain from translating words into thought. The hypothesis of special creations turns out to be worthless."

Cuvier carried the creation theory to an extreme. He believed with d'Orbigny that the great convolutions of Nature, which he ascribed to volcanic eruptions, had killed and would kill everything alive, and that new specimens had to be created in the place of those destroyed. This view is now altogether abandoned. Yet it contained, as Frech has recently shown, a sound nucleus. We need only replace the volcanic eruptions by the great climatic changes which are generally known as the glacial periods. During those periods many species of plants and animals were destroyed, and they were soon afterwards, when the cold had gone, replaced by new species which had survived or had meanwhile been evolved.

The American physiologist Jacques Loeb has

drawn attention to the influence of the alkalinity of the sea-water upon the production of cross-breeds. In ordinary sea-water eggs of a Californian sea-urchin, *strongylocentrotus purpuratus*, are not fertilised by the semen of the star-fish, *asterias ochracea*. If, however, a four per cent solution of caustic soda is added to the sea-water, in the proportion of three or four cubic centimetres per litre, the fertilisation is entirely successful. Since now the alkalinity of the sea-water increases during periods of low percentages of carbonic acid in the air, it is not unlikely that during the glacial periods new species may have been produced while life in general was much enfeebled. When the warmth returned and the soil was free again, a competition arose, so to say, with the new species, and the better fitted species will have found favourable conditions for their development.

Before we leave the discussion of panspermia, we may perhaps touch upon certain correlated features which have quite recently been elucidated by experimental researches. The possibility for living organisms to wander, by the aid of the radiation pressure, from one planet to another belonging to a distant solar system is conditioned by the low temperature of space. Low temperature can so strongly check and diminish the vital activity that life may be sustained for millions of years. Madsen and Nyman, as well as Paul

and Prall, have conducted some very remarkable experiments on the influence of temperature on the preservation of life. The former examined the endurance of anthrax spores at different temperatures. At low temperatures, in an ice cellar, for instance, they can be preserved for months without losing much of their germinal powers, whilst a few hours at 100 degrees will kill them. It is interesting that temperature here exercises the same general influence as upon special vital processes. Reactions generally take place two and a half times as rapidly as before when the temperature is raised by 10°. I have made this ratio the basis of my calculations concerning the preservation of the germinal power at low temperatures.

While these experiments were conducted at temperatures above the freezing point of water, those of Paul and Prall were performed at the boiling point of liquid air, at —195°. They took vegetative organisms (not spores) of staphylococci (a kind of bacteria) in the dried state. At ordinary (room) temperature half of the bacteria perished within three days; but their vitality did not decrease noticeably, when they were kept for four months at the temperature of liquid air. That is a very beautiful proof of the remarkable preserving influence of intense cold upon the germinal power. We assume that the most intense cold prevails in the empty space intervening between solar systems.

We might revert to the comparison between the problems of the "perpetuum mobile" and of spontaneous regeneration in one respect. Experience forces the conviction upon us that eternal movement under performance of work is impossible, considering the actual conditions on the Earth and in the solar system in general. But we must also admit that the one exceptional case which Maxwell suggested might play an important part upon nebulæ, those cosmic bodies which may be regarded as the counterparts of the suns. Thus although, as far as we can judge, spontaneous generation is no longer possible on Earth and probably was no longer possible under the similar conditions of previous ages, this phenomenon might conceivably take place elsewhere in the Universe, under materially different physical and chemical conditions. From the spot or from the spots, where spontaneous generation was possible, life might have spread over to the rest of the habitable bodies of the Universe. When we take the idea of spontaneous generation in this sense, it becomes much more probable than when we assume, that life would have arisen without germs on every one of the infinite number of cosmic bodies, on which we fancy it to thrive.

It is clear on the other hand that the world, taken as a whole, has been in existence for infinite ages and under conditions similar to those which prevail at present. Hence life must always have

been in existence, however far back we may carry our thoughts.

In this last chapter we have striven to prove that, before the fundamental laws of Nature (those of the indestructibility of energy and of matter) were definitely formulated, these laws had more or less consciously been in the minds of the various philosophers. It might possibly be said, that it would have been much more reasonable to accept the views of those philosophers without further ado and without waiting for their verification by scientists. That might pass if different, directly contradictory opinions had not so often been proclaimed at the same time. Under those circumstances verification by experiment was indispensable.

There is further a great difference between those philosophical speculations and the later deduced laws of Nature. When, for instance, Empedokles or Demokritos teach that matter is imperishable, whilst their time generally held the opposite view, that is something entirely different from Lavoisier's demonstration, that a metal becomes heavier by absorbing oxygen from the air, and that the increase is exactly equal to the weight of the oxygen bound by the metal. This experiment of Lavoisier is only one of the many demonstrations given by chemists every day which prove that the conclusions drawn from the theory of the indestructibility of matter never mislead us.

It is similar with the philosophical considerations of Descartes, Leibniz, and Kant concerning the gradual self-combustion of the Sun. There was a dark suggestion of the idea that energy cannot rise from nothing. But it was only after Mayer's and Joule's experimental demonstrations that, whenever a certain quantity of energy disappears (for instance, in the shape of work) a corresponding quantity of energy is always generated (for instance, in the shape of heat), that we could assert with perfect certainty, that the energy store of the Sun must, owing to radiation, continuously decrease and finally be used up altogether, unless it can be replenished in some way or other. Before this fact was fully recognised, the most ingenious men like Laplace and Herschel had found no contradiction in the assumption, that the solar radiation might continue in all eternity without decrement. This is indeed still the common notion, as it seems to agree with our daily experience. Kant's idea of the ever-recurring renewal of the Universe which—so generally held — deserves all praise, brings us yet into contradiction with the principle of the indestructibility of energy. The same criticism must be applied to the thesis of Du Prel.

With Kant the idea of repetition in the history of the Universe is based upon an ethical principle. He finds " contentment " in the thought that the world will continue to bear organic life. It would

interfere with his belief in divine perfection, if the suns were to remain for ever extinct. Spencer starts from a more objective point of view, when he assumes that there is a certain regularity in the development of the Universe. He stands on the modern platform that the world has been in existence through infinite time—while Kant thought that it had been created—and that it cannot have an end. His alternating periods of concentration and of diffusion of matter remind us of the Indian periods of rest and of activity. The solar system, Spencer considers, is a system in moving equilibrium which will finally be so distributed that it again becomes the attenuated matter from which it arose. How such a dissipation was to be brought about, since nothing but the one impelling force, Newton's gravitation, was known, is incomprehensible. Spencer certainly speaks of collisions between celestial bodies, but he does not ascribe any importance to them and does not make them factors in his diffusion phenomena. If there were no repelling forces, all things in the Universe would concentrate.

The introduction of the conception of the radiation pressure and the proof that, under certain conditions, entropy may decrease, have at last enabled us to work out the idea of an eternal cyclic development of the Universe, on which Indian philosophers were brooding in the grey past.

Ideas fare like organisms. Seeds are sown in multitude, but only a few will sprout ; and of the living organisms which rise from them, most succumb in the struggle for existence. There is an analogous selection of the fittest in the thesis of natural philosophy. We often have to hear that it is useless to trouble about theories, since they rise only to be overthrown again. Whoever speaks thus, lacks insight into evolution. The theories which we accept at present have their roots in notions which go back to the earliest ages. From dim dark notions they have grown into clearly defined doctrines. The vortex theory of Descartes had to be abandoned, when Newton demonstrated, that there could not be any great quantities of matter in space. But other speculations of Descartes, his suggestion of the formation of the solar system from a nebula in original rotation, for instance, have survived. We also recognise his immigration of planets from space into the solar system in the view of Laplace, that migrating comets had their share in the formation and movements of the planets, as well as in the suggestion, that the attraction centres of the planetary nuclei in the solar system, had come from outside.

Nothing can be more mistaken than to state that time spent in theorising on cosmogonical problems is wasted, and that we shall never advance beyond the knowledge of the ancient

philosophers, simply because we admit that their speculations contained elements of truth. Modern cosmogony has indeed advanced at a far more rapid rate than ever before, and the obvious reason is that natural science is flourishing as it has never done before. We may rejoice to observe, how humanity has been progressing at an accelerated pace in the course of centuries. This book contains many an exemplification. It will not be denied that, on the whole, the conceptions of an all-embracing nature and of freedom and manhood have advanced and receded simultaneously. Culture and civilisation expand, when the human race advances. And we find in particular that the scientist has, in all ages, spoken for humanity.

He who opens his eyes to the possibilities of evolution in their endless variety will abhor fraud and violence and disdain prosperity at the expense of his fellow creatures.

THE END

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